Science, Technology, and Innovation in Chile

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Contents

Foreword

The past decade has witnessed the flowering of closer ties between Canada and Chile — at the economic level as trade and investment have burgeoned, at the political level as Chile has emerged from dictatorship to civilian rule, and at the cultural level as Canadians have increasingly begun to view themselves as citizens of "the Americas" in the broadest sense. Somewhat less visible, perhaps, is the ongoing link between Canadian and Chilean research communities, fostered in large measure by the activities of the International Development Research Centre (IDRC), which has a long history of supporting research in Chile. Thus, it was with pleasure that it coordinated a review of Chilean programs for science and technology (S&T) last year. This project was undertaken with a sense of shared purpose, since Canada and Chile share the challenge of creating a vital "national system of innovation" (NSI) to serve the needs of their resource-based economies.

In August 1997, a conversation between Canadian Prime Minister Jean Chrétien and Chilean President Eduardo Frei during an Asia-Pacific Economic Cooperation (APEC) meeting raised the possibility of collaboration to assist Chile in a review of its S&T policies. This was prompted in particular by concerns in Chile regarding the limits of the current resource-based industrialization model being followed by that country. As an outcome of this initial contact, an agreement was reached in early 1998 for a project to be jointly funded by IDRC and the Chilean National Council for Science and technology (CONICYT) and managed by IDRC.

The exercise followed the same general lines as earlier national reviews carried out by IDRC in South Africa, China and Vietnam — although in this case with a more detailed focus on the management of research grant programs managed by CONICYT. Following initial consultations on terms of reference, an international team (Jim Mullin, Canada; Janet Halliwell, Canada; Robert Adam, South Africa; and Larry Milligan, Canada) was selected in consultation with CONICYT. This team undertook a fact-finding mission in August 1998. A mission report was then prepared in English and Spanish, and shared widely with stakeholders in Chile. This set the stage for a return visit by the review team in January 1999 to present their findings and discuss them with Chilean stakeholders.

The resulting report provides a detailed look at Chilean science and technology policy, using the notion of an NSI as means of organizing the discussion. While not intended to propose concrete reforms, the report does advance a series of suggestions for future action by Chilean authorities, ranging from mechanisms for interministerial coordination, to the reform of public-sector technology institutes, to policies for training of scientists and engineers.

IDRC is grateful for the opportunity to collaborate with CONICYT in this review, and hopes that the publication of this report will contribute to ongoing debate and discussion in the country. We are particularly indebted to Mauricio Sarrazin, President of CONICYT, who along with his staff has helped to ensure the success of this exercise. Thanks are also due to Ambassador Tomás Letelier and Marcela Yentzen of the Chilean Embassy in Ottawa, who enthusiastically supported the review from the outset.

Pierre Beemans

Vice-President, Corporate Services

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October 1999

Executive summary

Origins of the study

In August 1997, at the time of an APEC meeting in Vancouver, Canada, the president of Chile and the prime minister of Canada agreed that their countries would jointly commission a review of Chile's policies and programs of support in the areas of science, technology and innovation, given the importance of these activities to national economic performance in today's world of globalized competition among enterprises and economies. Later, during detailed consultations between representatives of the two governments held in Santiago, Chile in January 1998, it was agreed that CONICYT would act on behalf of the Government of Chile, while IDRC would act on behalf of the Government of Canada.

Formal terms of reference

The overall objectives of the study were to review, assess and report on:

- the policies, programs, priorities and policy instruments managed by CONICYT to promote the development and application of S&T within Chile;
- the interactions between CONICYT's principal policy instruments such as Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT) and Fondo de Fomento al Desarrollo Científico y Tecnológico (FONDEF) as well as other similar policy instruments supporting Chilean scientific and technological activities, particularly those coordinated within the Programa de Innovación Tecnológica (PIT) and the impact of those instruments on the performance of scientific and technological activities within Chile's universities, enterprises and governmental S&T institutions; and
- the policy and institutional environment within which CONICYT operates.

Additional, more detailed terms were set for the evaluation of CONICYT's two principal funds, FONDECYT and FONDEF. These terms are set out later.

The use of the "functions of a national system of innovation" as a policy framework

In this report, we define "innovation" as the introduction into a market (economic or social) of new or improved products, processes or services. This simple definition draws attention to the importance of markets. Successful research or technological development programs that are designed to promote innovation must take full account of the constraints imposed by the market into which the innovation is to be introduced.

We would underline our belief that, depending on the specific circumstances, the products, processes or services in this definition may either be physical or intellectual. Innovations occur in all aspects of the life of a society, and not only in the economic market place where the term is most often used. The theory of relativity became an innovation in the market for ideas in theoretical physics when it was widely adopted. Its author, Einstein, was rewarded with prestige and respect — the currency of that market place.

In the industrialized countries, and in a growing number of newly industrializing countries, policymakers have found that the concept of an NSI provides a **useful framework for technology policy formulation**. This is because it makes explicit the many different kinds of necessary inputs to produce an economy that is innovative, and hence competitive, in today's increasingly globalized markets. We have chosen this framework as a means both of organizing our findings and of structuring our questions about what Chile is now doing. However, we do **not** treat the concept as a model to be implemented. We believe it is a useful and helpful guide to the analysis of a complex reality, rather than a prescription for ways in which to organize either institutions or programs.

Many countries today support programs of research to generally advance knowledge, in addition to programs that are designed to promote technological innovation. In those countries, a key question for public policy revolves around the relative allocation of resources from all sources to these two lines of scientific and technological activity.

For the purposes of analysis, an NSI can be thought of as a set of functioning institutions, organizations and policies which interact constructively in the pursuit of a common set of social and economic goals and objectives, and which use the introduction of innovations as the key promoter of change.

The phrase "system of innovation," as it is used in this paper, is a powerful metaphor for describing the many interactions among various participating institutions, organizations and firms, most of which operate independently of each other. The system encompasses some interactions that are cooperative, others which are competitive. In our use of this term, there is no single entity with the power to control the workings of the system — but there are many which exert significant influence over it.

The report reviews six sets of "functions" of Chile's NSI:

Central government functions

1. policy formulation and resource allocation at the national level;
2. regulatory policy-making;

Shared functions (involving the public, private and academic sectors)

3. financing innovation-related activities;
4. performance of innovation-related activities;
5. human resource development and capacity building; and
6. provision of infrastructure.

Policy formulation, resource allocation and regulatory policy-making

The Government of Chile should give serious consideration to providing itself with a mechanism to permit it to look at the full range of policies which it is implementing in order to harness technological change to the benefit of Chileans and to ensure that the interaction of these policies with other policies of government is understood.

In a country that has no functioning high-level mechanism to look broadly at science, technology and innovation policies, it is not surprising that there is no discussion of the subject of a "science budget." That is, there is no means of displaying annually all of the proposed expenditures of government relating to its science, technology and innovation policies. This management tool will become necessary if government at the highest levels decides to become more involved in these issues.

Financing of innovation-related activities

CONICYT and the context for evaluating its main funding instruments

Many of the issues and problems to be discussed in this report are intertwined with issues and problems outside the direct purview of CONICYT, including:

- the lack of an overarching government policy framework and coherence of structures for R&D, S&T and innovation;
- the culture of universities, institutes and the private sector — cultures that reinforce separation and different values, rather than converging interests and mutual interdependence of their futures (as in an effective NSI);
- the aging of university academic staff coupled with the lack of well-paid employment opportunities for the highly trained personnel who graduate from Chilean universities;
- the mechanism whereby universities in Chile receive their base funding and the behavioural implications of that mechanism (that is historical and inadequately linked with public policy and purpose); and
- the overall funding level for S&T.

Even within this complex policy context, and notwithstanding the broad base of support for the professionalism of the CONICYT and its two main funds, FONDECYT and FONDEF, the CONICYT system is seen as needing significant change in order to

serve an effective role in supporting knowledge activities of high quality, impact, and which promote an evolving system of innovation in Chile.

As a basis for discussing possible directions for change, CONICYT's major funds are discussed in the context of the four terms of reference established for this review:

1. the ability of the instruments to meet established objectives;
2. the performance of the instruments in assuring quality, relevance and sustainability;
3. the capacity of the instruments to respond to changing needs, opportunities and research paradigms; and
4. the adequacy of the resource base.

FONDECYT

Overall, FONDECYT and its Superior Councils have significant support from the research community for professionalism, integrity and commitment. The FONDECYT programs have strengthened the Chilean capacity for research and instilled a culture of open dissemination of research through publications in refereed journals. However, the program delivery mechanism is unduly dominated by academic interests and a narrow disciplinary approach to research, so that there are inadequate linkages between the processes of discovery and utilization of knowledge. In fact, the FONDECYT Council appears to believe that the larger policy matters and promotion of S&T are not, and should not be, within its mandate.

We received comments from researchers, university administrators and FONDECYT officials concerning the processes used to assess quality and to allocate resources among competing projects. Overall, the program administration is seen as being transparent and honest, with a consistency of approach that was admirable. At the same time, a number of problem areas were identified:

- the system of external reviewers;
- the emphasis on publication counts;
- the need for more predictability; and
- the need for administrative flexibility.

Our impression of FONDECYT is that it has provided a credible and useful program structure that has the virtues and constraints of consistency. There have been only incremental changes in the core program areas until recent years, at which time a new program was introduced, Fondos de Estudios Avancados en Áreas Prioritarias (FONDAP), rather than a fundamental change of the existing project program. The FONDECYT Superior Councils noted the lack of an explicit mandate to take an active role in the development and promotion of S&T, and that other program initiatives had been limited by the lack of resources. We noted additional limitations in regard to

adequate staff infrastructure and a governance structure that more adequately represents the diverse stakeholder communities.

In recent years, the world of research has been experiencing transformation, or at the very least, transition in how knowledge is generated, stored, transmitted and used. This includes transformations in the motivations, operation and organization of knowledge in institutions and their relationships with society. The new mode of generating knowledge is not designed to supplant, but rather to compliment more traditional investigation. This new mode is characterized by:

- operating within a context of application — problems and issues are defined and research organized in response to a particular context or application articulated outside the discipline or field of research;
- exhibiting trans-disciplinary characteristics — the research conceptualization and methodology goes beyond the cognitive and social norms for any one discipline;
- possessing heterogeneity and organizational diversity — the research team requires a diversity of skills and experience that change over time and in response to the evolving research requirements; and
- having social sensitivity and accountability — inclusion of social considerations in setting the research policy agenda, the decision-making and performance evaluation process. It recognizes that social values influence research directions.

Despite the controversy surrounding its birth, FONDAP represents a dramatic step in the evolution of long-range research in Chile. We cannot fail to notice the close alignment of the FONDAP objectives with the characteristics of the evolving and important modes of research identified above. The program has the potential to catalyze research that bridges the boundaries between traditional fields of investigation, by virtue of its focus on research themes, rather than disciplines, and the active encouragement of groups of researchers who work in an international context.

FONDEF

FONDEF was designed to provide a means of enhancing R&D related to national needs, while retaining a strong commitment to open market forces and the belief that governments cannot pick winners. At the time of its initiation, government recognized inadequacies in the S&T capacity in universities and technological institutes, as well as the positive externalities in public support of programs and projects

Four specific issues should be seen as priorities if CONICYT is to increase the effectiveness of FONDEF:

1. Increase the participation of companies, especially where the sector is not well developed in Chile (such as in manufacturing and value-added products). Encouraging meetings between regional and industrial sector is one such vehicle.

2. Encourage further evolution of the R&D culture in universities. This could be achieved by increasing the number of interdisciplinary projects, which entail inter-university, university-technical institute and university-company cooperation. Creating incentives for people to move between industry and university (in both directions) would be particularly effective.
3. Increase the level and quality of project management, especially of complex projects. This will require an explicit human resources thrust that produces technicians and managers as well as scientists and engineers.
4. Streamline program administration.

The future evolution of FONDEF will be conditioned by the evolution of an innovation culture within the private sector and the portfolio of program instruments around it, as much as through its own design. Situated within CONICYT, FONDEF has a key role in linking discovery with synthesis and application. As the most long-range element of the PIT portfolio, it reinforces the importance of the science-base in the national and regional systems of innovation. Its capacity to evolve will mirror the policy capacity of its governing bodies (FONDEF and CONICYT, and to some extent PIT) to continue to situate the program at a dynamic interface of research performers and users in Chile. The evolution of a Foresight-like tool (Martin and Irvine 1989) would be one means of creating an environment of continuous evolution within FONDEF.

CONICYT and policy development

Since its creation in 1968, CONICYT has had either explicit or implicit responsibility for defining policy at two different levels. It has had a responsibility in law for the provision of broad advice to the president of the Republic on matters of S&T policy. It has had the operational responsibility to manage its resources well, which implies a responsibility for developing internal policies to guide its own activities.

Earlier, we indicated our belief that the Government of Chile needs to define a mechanism to deal with science, technology and innovation policy at an overall level. Once a decision on that mechanism is taken, any ambiguity in the role of CONICYT with respect to advising on broad policy issues should be removed.

No matter what happens to CONICYT's role in national policy advice, we believe that steps should now be taken to improve its capacity to deal with operational policy issues in ways that take into account the needs of the constituency it serves and the changing global patterns of research organization and financing.

We believe that the time is ripe for a new Board or Management Council to be appointed to oversee the activities of CONICYT. It will play an active role in the development of policies regarding the use of the funds that will be allocated in future to CONICYT. In line with well-established practice around the world, the council should

be of manageable size (say fifteen members), and have its membership drawn from the public, private and academic sectors. Members can serve on the council in a personal capacity, with the President of CONICYT as a member of that Council. The President of CONICYT could chair this council, as is the practice in many similar bodies around the world. The Council should also contain at least one member with functions relating to the operation of the Corporación de Fomento de la Producción (CORFO) funds. This will ensure clear articulation among the complementary roles being played by CONICYT and CORFO in the support of technological development.

CORFO funds

A challenge for FONTEC would be to stimulate more innovation in areas that will clearly be strategic in the 21st Century, particularly in the application of information technology (IT) and biotechnology widely throughout the economy. As the primary government supply-side instrument for innovation in the Chilean business sector, FONTEC has the responsibility not just to respond to project proposals. It must develop a culture of innovation in those areas that PIT's foresighting activities have already identified as being critical for knowledge-based economic growth in the future.

Any analysis of FDI must be done in conjunction with an analysis of the effect of baseline funding removal on the CORFO institutes. The reasons for the complete shift to competitive project based funding were:

- to widen the access to government funding for innovative projects from all sources and not merely from a few "privileged" institutes; and
- to ensure that government knows exactly what it is getting for its investment in innovation.

While these two points are based on powerful principles, it is clear that a danger of this fairly radical approach could be to undermine Chile's potential to perform strategic research. The CORFO institutes are bound to focus more on short-term, bottom line projects. The challenge for FDI will be to identify key strategic themes effectively — and to channel funding accordingly.

The funds coordinated by the PIT face three main challenges:

1. To facilitate the level of strategic research that is normally conducted by state-funded institutions (such as CSIRO in Australia, MINTEK and CSIR in South Africa), following the decision to shift all funding away from the technological institutes towards competitive, project-based funding.
2. To coordinate (or even amalgamate) the various funds in a creative way that is not excessively rule-bound, given that only a limited degree of content differentiation appears to exist, particularly between FONDEF, FONTEC, and

FDI. Even for these general funds, the main focus is on agriculture, forestry and fisheries, generating a possibility for overlap with FIA and FIP.

3. To support innovation that is consistent with plans for and which assists current patterns of economic growth. This will perhaps be the most onerous challenge. Clearly the strengths in Chilean applied research currently lie in agriculture, forestry, and fisheries. It is in these areas that the majority of innovative proposals originate. However, today the Chilean economy is growing much faster in the industrial, commercial, infrastructure, and service sectors. Researchers should, therefore, be actively encouraged to align their proposals with these changes. A better focus of effort will bring benefits not only to the economy but also to the researchers themselves, because these new areas are clearly where local and international private-sector investment will be channelled.

Performance of innovation-related activities

The universities

The research-funded universities are the principal sites for basic and applied research in Chile. Because of this, these centres stimulate a huge amount of interest among young Chileans who are pursuing research. These are important and appropriate roles for such institutions so public policy should ensure that such universities have the means available to fulfill the tasks involved.

We welcome the proposed review and accreditation of universities that is supposed to be undertaken within the MECESUP investment now being launched by the Ministry of Education with some support from the World Bank. This process should entail a review of research activities and result in investment in research infrastructure and salary levels as well as in student research support in those locations identified as demonstrating excellence.

There is a widely acknowledged need for Chile to come to terms with the aging both of its research system and of its university faculty.

Development of a strong, popular, post-graduate research system will be evolutionary, requiring the achievement of recognition of domestic graduates and the provision of employment opportunities. In the meantime, a great deal could be achieved for innovation in Chile by creating expanded opportunities for graduate students and new opportunities for undergraduate students to obtain research experience. These two groups will impart vitality to the process and be receptive to the use of new knowledge after leaving university.

Technological institutes

We visited a sampling of six institutes, three of which were CORFO organizations — la Corporación de Investigaciones Tecnológicas (INTEC), el Instituto Forestal (INFOR), and el Instituto de Fomento Pesquero (IFOP). The other institutes included in our sample were the Fundación Chile, el Instituto Nacional de Investigación Agropecuaria (INIA), and el Centro de Investigación Minera y Metalúrgica (CIMM).

Although most do some research, their attention is really and properly focused on problems of development and adaptation, as contrasted with the FONDECYT emphasis on basic discovery. There was only a little evidence of connection between the institutes and universities. It was disturbing to find that INIA, for example, now perceives universities as competitors for funding rather than as the partners that they were in the past. Making researchers' salaries dependent on them winning research grants must heighten this sense of competition.

The current emphasis on competitive funding for the technology institutes is intended to have them operate in a manner more directed to client and national needs than previously was the case. The manner in which the competitions are operated would then have a very real shaping influence on the institutes. It would be logical for the intended clients to have a significant role in this. We have only limited information on this point. It would seem, however, that today's level of dependence on competitive funds by CORFO institutes means that, out of necessity, they have pursued funding from financing sources which do not insist on close client linkages at the expense of retaining the sought-after client orientation.

Firms in the private and public sectors

Official statistics show that the Chilean private sector currently funds about 18 percent of the country's R&D, but performs a mere 3 percent of these activities. If this figure is accurate, it reveals an astonishing gap in the NSI. One reason why 3 percent might be a serious underestimate is that expenditure on R&D is not recognized explicitly as a tax write-off, and is counted merely as a general cost.

When we interviewed business leaders on the topic of innovation, the following issues emerged:

1. Although there are strong links between business and universities, particularly at the human-resources level (for example, there is a tradition of part-time professorships being held by businessmen), the university mentality is not geared to solving problems within a business timescale. This is a frustration. Funding is not nearly as much of a problem as is the orientation of the researchers.
2. Patenting is not well developed in Chile. It is hard to measure what constitutes the real outputs of R&D.

3. There are real success stories of industry-university collaboration. In the case of REUNA, the Chilean Internet company, several years were gained by the farsightedness and drive of engineers with strong university links.
4. Venture capital is hard to obtain and it is difficult to convince financial institutions of the value of knowledge-based industries. To obtain funding for innovation which is entirely new, rather than simply incremental, is also very difficult. A concerted campaign needs to be run to change this.
5. Generally, the PIT funding system does not take industry's advice as to which areas of research are important. There is a need for the state to support long-term research, rather than simply reacting to the proposals of researchers. The method of Technology Foresight should be investigated.
6. Indirect incentive mechanisms such as tax credits should be urgently investigated.
7. Knowledge-diffusion mechanisms in Chile are completely inadequate, particularly with regard to supporting SMEs. The government places a lot of emphasis on generating knowledge, but none whatsoever on diffusing it.

The private sector effort is central to any program to embed innovation in the economic life of the country. It is essential, therefore, to develop a good portfolio of measures to stimulate and support innovation in the private sector. Recently, with the introduction of funds such as FONDEF and FONTEC, Chile has begun to support direct incentives. However, a great deal of suspicion still exists with respect to indirect incentives. Although this caution may prove well founded, there is a growing body of international experience in tax incentives for R&D and innovation that includes many positives. We strongly recommend that Chile acquaint itself with this information by means of a formal study.

Human resource development and capacity building

We were struck that research training was considered training for a research career, rather than training for a broader set of career options requiring the competency for independent thought and analysis of complex problems (including, but not limited to, academic positions). We are not advocating a move from a research-based graduate program, or the requirement for an in-depth investigation in a specialized area. Rather, it is recognizing the value of providing a range of educational opportunities in the context of the core graduate education that equip a graduate for a more diversified career. This might include business management, technology management, or information technologies, among other disciplines.

We have heard that the training of professional technologists — those skilled people with a practical rather than theoretical basis to their training — is relatively neglected in Chile, as it is in almost all other countries of the region. This should be a

concern to policymakers since the internal levels of technological competence needed throughout firms are increasing. Therefore, more and more entry-level positions will need young people with a solid basic education in technology. Colleges provide one means of addressing this need.

One of the dominant features of the research community in Chile is the small size of the typical research groups in most of the institutions that we visited. Only in a few locations were we conscious of attention being paid to the tasks of research management. The skills involved are complex, even more so when applied to the process of technological innovation with its requirements of blending the contributions of science, technology and the skills of the market place. However, as in almost all countries, Chile operates on the unsubstantiated hypothesis that the best researchers are automatically the best research managers. It is our belief that there is an established pool of knowledge in the area of management of research which can and should be accessed by those Chileans in who will undertake leadership roles in Chile's NSI.

Provision of infrastructure

The introduction of technical barriers to trade as a strategy in international commerce makes the Instituto de Normas Nacional (INN) a highly strategic body. The norm for national expenditure on standards is likely to be revised upwards in the face of globalization and WTO prescriptions. During the 1980s, the norm for industrialized countries was about 0.2 percent of industrial output. This would mean a Chilean investment of approximately US $80 million per annum.

The lack of emphasis on patenting in the Chilean research system is worrying. Recent evidence demonstrated by the rates of citation of research articles in US patent applications indicates that there is an increasing connection between high-quality scientific research and innovation. FONDECYT, FONDAP and even FONDEF are currently not sensitive enough to difficulties experienced by researchers in reconciling the bibliometrically-based evaluation criteria for funding with the requirements of patenting their work.

Chile currently has a telecommunications infrastructure and portfolio of services to rival any in the world. This is a crucial contribution to the level of competitiveness of the Chilean economy.

The creation of the Red Universitaria Nacional (REUNA) has been decisive in the development of Chile's Internet access and must rank as one of the singular successes of the FONDEF program. FONDEF has succeeded in stimulating collaboration between academic researchers and the private sector in an absolutely key area. The result is that Chile now has the largest number of Internet hosts per unit of population in Latin America.

The commitment to an excellent library service is not surprising in a research system which emphasizes publication to the extent that Chile does. Nevertheless, it is heartening that university authorities have had the foresight to invest in modern infrastructure and are sensitive to the needs of researchers in this regard.

Chile is extremely fortunate, probably more so than any other country at an equivalent stage of development, in possessing the natural conditions to enable it to attract major international scientific infrastructure. The only developing countries which have attracted equivalent scientific interest — unfortunately unmatched by infrastructural investment — are those in the Middle East and Africa, both of which are rich in archaeological and cultural deposits.

It is encouraging that in the most recent agreement to build another foreign-financed telescope in Chile, the government has included a provision in the contract to ensure the participation of Chilean engineers in the construction and infrastructure activities. Gaining access to challenging assignments is an advantage for Chile's engineering profession also.

Policy issues emerging from the review

The review provides an introductory discussion of some topics that should be addressed in Chile:

- institutional governance;
- the need for prioritization;
- technology for SMEs;
- promoting an innovation "culture" in Chile;
- support for the social sciences; and
- support for health research.

Among the items on this list, the question of setting priorities is particularly sensitive. One cannot argue with the remarkable economic success achieved by Chile using basic market principles and it is tempting simply to affirm that an S&T system based on competition will inevitably result in similar high levels of achievement.

The question, however, is whether the competition underlying Chilean S&T policy has anything to do with a real economic market. Innovation is part of a competitive strategy, not merely an analogue of it. Even in fields close to the market, lag times of several years are normal. Given the strategic and long-term nature of research, the innovator needs to anticipate markets and to choose areas where there is a potential advantage. If funds to promote innovation are to work optimally, they should also be able to anticipate strategic areas. The beginnings of such an approach are to be seen in FONDAP, and the large astronomical observatories offer a huge advantage to Chilean astronomers.

Chilean scientific culture values transparency and clearly stated criteria. A way to arrive at such criteria, mediated naturally by competitive rules, would be to conduct a Technology Foresight study. In such a study, a very large section of the S&T community would itself be involved in determining strategic foci. The programs and projects which flowed from this process could not be labelled as arbitrary. In a country where the availability of resources is not high, these choices need to be made to give the most promising areas an appropriate critical mass.

Beyond these points, we end by proposing an "Agenda for Innovation Policy" in Chile that deals with nine substantive topics, within which we identify key issues for debate.

1. Focus on innovation: How can we stimulate a national policy discussion on the support of innovation?
2. Lack of policy framework and high-level structures dealing with innovation: Will the Government of Chile assign responsibility for overseeing innovation issues to a high-level government mechanism?
3. Strengthening CONICYT both as an institution and the operation of its funding mechanisms: Will the Minister of Education reform the governance structures of CONICYT? Will CONICYT, FONDECYT and FONDEF make adjustments in their policies? Will they streamline and simplify the administrative procedures that they use in discharging their mandates?
4. Participation of the private sector: How can government engage the private sector in some joint commitments with respect to long-term investments in Chilean science, technology and innovation?
5. Policy for support of SMEs: Is the government prepared to design and implement a technology extension system suited to the needs of Chile's small- and medium-scale enterprises?
6. New company start-ups: Will the government take the initiative to foster both the opening up of a market for venture capital, and sources of training for entrepreneurs in the required business skills?
7. Policy for the future evolution of technology centres: Is government prepared to reform the governance structures of technology institutes and competitive funds to provide for adequate representation of the private sector on their respective boards? Will government negotiate performance contracts for those activities which it expects the institutes to perform in support of public purposes? Will it pay fair market prices and full overheads for services rendered?
8. Linking science, technology and innovation activities to regional development: How can regional authorities be convinced to allocate some of their spending to the promotion of innovative solutions to regional problems?

9. Human resource and institutional development: Will Chile, and in particular its financing bodies, allocate increased resources to human-resource development to counteract the aging trend visible in many of its science, engineering and technology institutions? Will more attention, in institutional capacity-building, be paid to the need to strengthen the technology management and commercial skills of key staff?

Background to the study

I. Introduction

Origins of the study

In August 1997, at the time of an APEC meeting in Vancouver, Canada, the president of Chile and the prime minister of Canada agreed that their countries would jointly commission a review of Chile's policies and programs of support in the areas of science, technology and innovation, given the importance of these activities to national economic performance in today's world of globalized competition among enterprises and economies. Later, during detailed consultations between representatives of the two governments in Santiago, Chile in January 1998, it was agreed that CONICYT would act on behalf of the Government of Chile, while IDRC would act on behalf of the Government of Canada in order to define the precise terms of reference for the activity, and to provide the necessary financial resources.

Detailed terms of reference were developed during consultations in Santiago in March, 1998, and an international team of experts selected to carry out the work.[1] Field work for the study was carried out in Chile between August 3 and 15, 1998.[2]

Formal terms of reference for the study

The following is the text of the full terms of reference approved for the study.

Terms of Reference for a Review and Assessment of
The Policies, Programs, Priorities, and Policy Instruments Managed by CONICYT

The overall objectives of the study will be to review, assess and report on:

1) the policies, programs, priorities and policy instruments managed by CONICYT to promote the development and application of S&T within Chile;

2) the interactions between CONICYT's principal policy instruments (FONDECYT and FONDEF) and other similar policy instruments supporting scientific and technological activities in Chile (particularly those coordinated within the Programa de Innovación Tecnológica) and the impact of those instruments on the performance of scientific and technological activities within Chile's universities, enterprises and governmental S&T institutions; and

3) the policy and institutional environment within which CONICYT operates.

In particular, the study will evaluate the design, management, performance and possible future evolution of FONDECYT and FONDEF with respect to:

a) the ability of those instruments to meet their established objectives relating to scientific research, technological development and human resource capacity building;

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[1] The membership of the study team is set out in Appendix 1.

[2] The detailed itinerary for the study is set out in Appendix 2.

b) the performance of the instruments in assuring the quality, relevance and sustainability of the activities supported, in the light of Chile's social, economic and cultural objectives;

c) their capacity to respond to changing needs, opportunities and research paradigms in S&T; and

d) the adequacy of their resource base, in the light of Chile's needs and macroeconomic situation.

The study will carry out the review and assessment required in the light of established international practice.

Given the focus of the study on FONDECYT and FONDEF, there was insufficient time to conduct an in-depth evaluation of some other important activities managed by CONICYT, including its activities in international relations, its work in allocating scholarships, its EXPLORA program (which provides information to schoolchildren on S&T), and its general assistance in the provision of S&T information. Our omission is not intended to imply that these functions are unimportant.

Structure of the report

The report begins with a discussion of the origins of the study and of the methodology used in its execution, with particular attention being paid to the approach used in assessing the performance of institutions, policies and programs within the framework an NSI. The section describing the background to the study concludes with a preliminary overview of the present actors in Chile's NSI. It provides an indication of the range of functions performed by each within the innovation system. The use of the concept of an NSI is a device to provide an overall framework within which to analyze and comment on the varied activities and institutions covered by the study's terms of reference.

The review then focuses, in order, on the various sets of "functions" within an NSI:

- national policy, resource allocation and regulatory policy functions;
- financing functions, including those managed by CONICYT;
- performance functions in the universities, technology institutes and enterprises;
- human resource development functions; and
- infrastructure functions.

This part of the report presents the information collected during the study.

The final section of the report deals with key policy issues identified during the study. It concludes with some thoughts on the elements of an agenda of issues relating to innovation policy which, in the view of the authors, should be addressed in Chile.

II. Methodology

General approach

Since the early 1960s, the member countries of the Organization for Economic Cooperation and Development, (OECD), through its Committee on Science and technology Policy of the Organization (CSTP), have conducted reviews of their own S&T — and now, innovation — policies using a well-established, three-step approach.

1. A careful design of a study to be conducted by a team of international experts with considerable experience in policies for and management of science, technology and innovation, and the preparation — by the government of the country to be reviewed — of basic information and data for the study.
2. An intensive set of interviews, conducted by the international team with senior people in positions related to science, technology and innovation in government, universities and the business sector, designed to provide the insights necessary for the preparation of a report which analyses the performance of the country and its institutions.
3. A set of discussions, often including public discussions, of the study report involving members of the study team and interested stakeholders within the country whose policies, programs and institutions have been reviewed.

This methodology has been used for studies in almost all of the industrialized countries over the years and has also been used successfully in studies sponsored by IDRC in South Africa and in the People's Republic of China (IDRC 1993, 1997).

Use of the "functions of a national system of innovation" as a policy framework

In this report, we define "innovation" as the introduction into a market (economic or social) of new or improved products, processes or services. This simple definition draws attention to the importance of markets, and underscores how successful programs of research or technological development that are designed to promote innovation must take full account of the constraints imposed by the market into which the innovation is to be introduced.

Depending on the specific circumstances, the products, processes or services in this definition may either be physical or intellectual. Innovations occur in all aspects of a society's life, not only in the economic market place where the term is most often used. The theory of relativity became an innovation in the market for ideas in theoretical physics when it was widely adopted. Its author, Einstein, was rewarded with prestige and respect — the currency of that market place.

In the industrialized countries, and in a growing number of newly industrializing countries, policymakers have found that the concept of an NSI provides a useful

framework for technology policy formulation. It highlights the many different kinds of inputs that are necessary to produce an economy that is innovative — and hence competitive — in today's increasingly globalized markets. We have chosen this framework to both organize our findings and structure our questions about what Chile is now doing. However, we do not treat the concept as a model to be implemented. We believe it is a useful and helpful guide to analyze a complex reality, rather than a prescription for ways in which to organize either institutions or programs.

There have been many attempts in industrialized countries to put forward a concise definition of an NSI. Freeman defines it as "*a network of institutions in the public and private sectors whose activities and actions initiate, import, modify and diffuse new technologies.*" (Freeman 1987) An alternative, fuller definition is "*a system of interacting private and public firms (either large or small), universities and government agencies aiming at the production of S&T within national borders. Interaction among these units may be technical, commercial, legal, social and financial, inasmuch as the goal of the interaction is the development, protection, financing or regulation of new science and technology.*" (Niosi et al 1993)

"System of innovation" is a powerful metaphor for describing the many interactions among various participating institutions, organizations and firms, most of which operate independently of each other. The system encompasses some interactions which are cooperative, others which are competitive. In our use of this term, there is no single entity with the power to control the workings of the system — but there are many which exert significant influence over it.

At the outset, it is important to understand that the relationship of research and development (R&D) to technological innovation is neither simple or linear. In addition to the direct contributions of novel ideas and commercial applications, indirect contributions through the advancement of knowledge and scholarship are an equally important feature of a system of innovation. Both types of scientific and technological activity support the provision of highly trained personnel, and the building of a broader capacity for the generation, dissemination, accessing, application and interchange of knowledge. A key question for public policy revolves around the relative allocation of resources to the various modes of doing research for any one economy and at any one point in time.

In earlier S&T policy reviews and policy development activities in South Africa and China that were also financed by IDRC, a good starting point has been the analysis of a series of six sets of "functions" which need to be present in an effective NSI. Broken into two broad categories, the six sets of functions are:

Central government functions

1. policy formulation and resource allocation at the national level;
2. regulatory policy-making;

Shared functions (involving the public, private and academic sectors)

3. financing innovation-related activities;
4. performance of innovation-related activities;
5. human resource development and capacity building; and
6. provision of infrastructure.

These sets of functions are described in Appendix 3.

The use of the concept of an NSI as a framework for policy is an attempt to signal a radical departure from the current situation and understanding. It replaces the old with a new view of the role and status of the sciences, (including the social and human sciences), engineering, and technology in national development. Many countries perceive that technical change is the primary source of economic growth. This means that economic and S&T policies must recognize that the two processes — innovation and technology diffusion — are central concerns which drive technical change.

An NSI is a set of functioning institutions, organizations and policies which interact constructively in the pursuit of a common set of social and economic goals and objectives, and which use the introduction of innovations as the key promoter of change.

Thus, the four key interests of any country can be thought of as being:

1. to ensure that it has a set of institutions, organizations and policies which give effect to the various functions of an NSI;
2. to ensure that there is a constructive set of interactions among those institutions, organizations and policies;
3. to ensure that an agreed-upon set of goals and objectives exists, which are consonant with an articulated vision of the future being sought; and
4. to ensure that a policy environment designed to promote innovation is in place.

The elements of an NSI — the individuals, organizations, and policies — are to be found in most countries. What distinguishes the successful from the unsuccessful NSI is its capacity to promote constructive interactions among these elements. If it exists, past patterns of lack of coherence, deep fragmentation of effort, and often enormous imbalances in access to resources can be overcome. This capacity springs from the mindset of the individuals and organizations within the system. It is not something created by decree.

The importance of interactions within an NSI was underscored in a major report (OECD 1991) when it was argued that:

> The interactive character of the innovation process calls for organizational structures and mechanisms to ensure the appropriate interactions and feedback inside corporations as well as among various institutions that make up the national systems of innovation. For both analysis and policy, this model underscores the importance of cooperation between firms and institutions, and, thus, the role played by links and networks involving different organizations. The growth of inter-firm alliances represents a major change in the area of innovation. These emphasize, in particular, the increasing symbiosis between S&T, the pervasive nature of some key, contemporary technologies, and the synergy and even fusion of some technologies.

Three principal reasons underlie the utility of the concept of an NSI as a basic framework for policy analysis.

1. It affords an opportunity to think of means for the promotion of coherence and integration among national activities.
2. It offers a means of identifying what needs to be done without automatically tying the necessary functions to any particular institution or organization currently in place.
3. It focuses attention on innovation — on doing new things in new ways — rather than simply on the production of knowledge.

The concept of "stakeholders" in a national system of innovation

Stakeholders are the set of individuals and institutions that influence and are influenced by the activities of an NSI. They may have different relationships with the system.

Stakeholders who are active participants in the system may play different roles in it. They may be policymakers or advisors, financiers of system activities, regulators, performers of SET activities, providers of education or training, or providers of infrastructure. They may be involved in one or more of the sectors of the national economy such as industry, agriculture, health, defence, environment, or transport. Stakeholders usually participate in the national system through their institutions or organizations. These institutions may, in turn, have multiple roles: for example, a university is both a performer and a provider of education and training. They also may participate individually (such as some universities) or collectively through some other institution (such as the Consejo de Rectores). Or, they may also have functions lying outside the NSI (such as universities that have activities in the classics, which is a cultural rather than scientific arena).

In any country, the principal groups of stakeholders in an NSI are to be found in government, the business sector, the education and training sector, within organized civil society, and among interested outsiders. A listing of Chilean stakeholder groups is provided in Appendix 4.

The analysis performed in this report was done within a matrix framework provided by the functions of the NSI and the identification of groups of its stakeholders.

Structure of the interview set

Within the limitations of a two-week period for interviews, an attempt was made to hold discussions with a wide variety of stakeholders within Chile's NSI. Given the particular attention which had been given to funding mechanisms and to FONDECYT and FONDEF in particular, most of those interviewed in universities and firms were people who had been supported by such funds.

The resulting set of interviews comprising the basis of the study's fieldwork is set out in Table 1.

Table 1. Organizations interviewed, August 3–14, 1998.

Type of organization	Specific people or institutions
Government minister, ministry or comisión	Minister of Foreign Affairs; Minister of Education
	Ministerio de Hacienda
	CONICYT y los Consejos de FONDECYT y FONDEF; la dirección de una Proyecto FUNDAP
	Ministerio de Economía, Secretaría de la Programa de Innovación Tecnológica
	Ministerio de Planeación
Government funding organizations	FONTEC, FDI, FIA
Advisory bodies	Comité Asesor de la Presidencia
Technological institutes	INIA, CIMM, IFOP, INTEC, INFOR, Fundación Chile
Universities	Researchers from Universidad de Chile, Pontificia Universidad Católica de Chile, Universidad de Santiago, Universidad Metropolitana, Universidad Católica de Valparaíso, Universidad de Valparaíso, Universidad Católica del Norte, Universidad de Antofagasta, Universidad de Concepción, Universidad del Bío-Bío, Universidad Austral de Chile, Universidad Nacional Andrés Bello
State corporations	Representative of CODELCO
Private enterprises	CTI, CTC-Internet, Bios Chile, SRC, Frutos del Maipo, CESMEC Ltda, INTELLICOMP, TEK Chile, CD Multimedia SA, Cooperativa Campesina Chacay y San Vicente Ltda

Limitations in the interview set

Any two-week program of interviews on a topic as broad as a review of an NSI is going to be subject to limitations and this review is no exception. The Chilean system of S&T has evolved over many years in the context of a changing political climate and an

increasingly globalized society. To pretend to have come to understand all dimensions of the system would be naive in the extreme.

The two largest gaps were those relating to the processes of policymaking and resource allocation within the Government of Chile and to the technological strengths and weaknesses of private-sector firms, and in particular of small- and medium-scale enterprises. In these areas, where we felt it to be appropriate, we have made comments on international experiences that may be germane to Chile, but we do so with less assurance than we have in other areas.

A third gap in our coverage lies in the area of intellectual property — both in terms of policy-setting and in the actual protection available in Chile. We did note that Chile does not have a strong tradition of using patent protection and believe that a study of present needs and attitudes would be worthwhile.

On the positive side, wherever we went we were met with interest and openness and so we had a rich array of opinions and ideas to draw upon. To use the metaphor which we used in introducing our mission, we hope that the image reflected through our "mirror" is one which attracts comment and stimulates discussion.

III. An overview of Chile's national system of innovation

One of the initial activities of the review was to attempt to construct a mapping of the stakeholders in Chile's NSI against the sets of functions defined in Chapter II. This was done by assembling brief comments in four matrices, the results of which are displayed in the following four tables. At this stage, the interpretation of the functioning of the system should be seen as preliminary. That task is tackled in greater detail in succeeding chapters of the report.

Given that qualification, Table 2, "The relative importance of stakeholders to the functions of the Chilean national system of innovation" gives an overview of the entire system at a very general level. It is followed, in Table 3, by a somewhat more detailed look at "The roles of government stakeholders in the functions of Chile's national system of innovation." Table 4 follows with a summary of the roles of all of the key stakeholders with respect to the implementation functions of the system. Table 5 deals with the roles of six of the main technological institutes in Chile (INTEC, INFOR, IFOP, INIA, CIMM and the Fundación Chile) with respect to the main implementation functions.

This mapping served to orient our analysis of individual functions and individual institutions.

Note: In the tables which follow, substantive comments are in plain type while *our comments on omissions are in italics.*

Table 2. The relative importance of stakeholders to the functions of the Chilean NSI.

	Core functions of government		Implementation functions			
	Policy and resource allocation	**Regulatory (policy level)**	**Financing of contract research or technical services**	**Performance of innovation-related activities**	**HRD and capacity building**	**Infrastructure provision for innovation**
Government	Should be key function, no policy coordination; does not see S&T as critical in resource allocations	Weak, but some improved use of regulatory policy to create a climate for innovation	Highly involved; many funds, without overall strategy or coherence	Significant instruments in form of technological institutes, but their function and performance needs review	Finances some universities via complex system but under-invests in other levels of technical training	Moderate (primarily through technological institutes)
Business (including state enterprises, especially CODELCO)	Not involved	Some limited functions in the national system of standards recently privatized	With a few notable exceptions, not involved	Generally assumed to be low; good examples exist but are not well known	Generally low investment level	Patchy — lack of tradition of using patent system
"Traditional" Universities	No formal link	No	Low due to limited university budgets	Key function, with patchy implementation	Key function	Key function (in fact too heavily involved)
Other educational institutions	No	No	No evidence	Low	Key function, with evolving capacity, but limited in S&T	None
Organized civil society	Limited evidence of activity by some professional societies	No	Significant role of the Church	No	No	No
Interested outsiders	Yes — strong role of international agencies (IDB, World Bank)	No	Yes	No	No	Yes (telescopes)

Table 3. The roles of government stakeholders in the functions of Chile's NSI.

	Core government functions		Implementation functions			
	Policy and resource allocation	Regulatory(policy level)	Financing (performance level)	Performance	HRD and capacity building	Infrastructure provision
Policy agencies	No central authority and no consideration of total government investment in S&T	*No visits made to regulatory groups in government*	Not a role	Not a role	Ministry of Education is playing an important role	*Not discussed by review team*
Congressional bodies	Have discussed broad issues, but no action has followed.	*Not discussed by review team*	Not a role	Not a role	*Not discussed by review team*	*Not discussed by review team*
Financing agencies	Ministry of Finance does not maintain a "science budget"	Not a role	CONICYT and the PIT support a full range of programs	Not a role	The funding agencies may have under invested in HRD	CONICYT and PIT provide support
Ministries	Some line ministries undertake sectoral initiatives	Some, like the Subsecretaria de Pescas, base regulations on S&T inputs	Ministry of Education is important in financing of universities	Are now being asked to sign "performance contracts" with institutes for R&D	*Not discussed by review team*	*Not discussed by review team*
Institutos tecnológicos	Not a role	A minority, including IFOP and INFOR, make S&T inputs	Some still subcontract, but the practice may be diminishing due to competitive pressures on budgets	Most are seeking ways to change in response to abrupt change in funding mechanisms designed to stimulate greater competitiveness	CIMM in particular has had a long involvement in graduate training	Some increasing attention now being paid to standards, metrology, and quality systems
State corporations	Not a role	*Not discussed by review team*	CODELCO is an important source of research contracts in its fields of interest	CODELCO is a significant performer of R&D	*Not discussed by review team*	*Not discussed by review team*

Table 3 concluded.

	Core government functions		Implementation functions			
	Policy and resource allocation	Regulatory(policy level)	Financing (performance level)	Performance	HRD and capacity building	Infrastructure provision
Armed forces	Not a role	Not a role	*Not discussed by review team*	Have some institutes	*Not discussed by review team*	*Not discussed by review team*
Fundación Chile (treated separately due to its unique legal status)	Not a role	Not a role	Does some subcontracting with universities	Is important, particularly in transfer of technology	Provides training	Yes, particularly in quality certification for several industrial sectors
Advisory bodies — el Consejo Asesora Presidencial	Has limited scope (deals only with basic sciences) and few secretariat resources	Not a role	Consejo Asesora Presidencial has a funding responsibility which may represent a conflict-of-interest	Not a role	Has not yet discussed the issue publicly	Not a role
Other advisory bodies	The now non-operational Council of CONICYT was originally designed to play this role	*Not discussed by review team*	*Not discussed by review team*	*Not discussed by review team*	*Not discussed by review team*	*Not discussed by review team*
Other levels of government	Not a role	Not a role	Chile's regional governments are beginning to play a modest role in financing S&T activities	Not a role	*Not discussed by review team*	*Not discussed by review team*

Table 4. Stakeholders and implementation functions of Chile's NSI.

	Provision of financing		Performance			HRD And capacity building		Infrastructure	
Stakeholder	**Grant & contract support**	**Incentives (including tax incentives and use of purchasing power)**	**Research development and innovation**	**Linkages and networks**	**Transfer and adoption**	**Tertiary education and training**	**Institutional capacity creation**	**Regulatory including intellectual property**	**S&T information**
CONICYT	Key player	Uses grants to joint projects as incentives to industry; heavily focused on incentives to individual researchers	Provides support	FONDAP is a beginning to promoting networks	An objective of FONDEF	Provides support, but this needs to be expanded	Not identified as a priority to date	No	Internal system is good, using international norms
PIT	Key player	Uses grants to joint projects	Provides support	Supports linkages, but not formal networks	Key objective behind all funding	No	Concerned, with CORFO, about the institutos tecnológicos	Has supported privatization of some capacity in standards	Supports a publishing program to highlight Chilean innovative activity
Government ministries	Limited	No evidence of consideration of use of purchasing power as an incentive to innovation	Largely done via institutos tecnológicos	Not common	Agriculture has extension functions in place	Ministry of Education a key player and about to introduce the MECE program to post-secondary education	Ministry of Education, via MECE, will provide resources for institutional capacity-building in universities	*Not discussed by review team*	*Not discussed by review team*

Table 4 continued.

	Provision of financing		Performance			HRD And capacity building		Infrastructure	
Stakeholder	Grant & contract support	Incentives (including tax incentives and use of purchasing power)	Research development and innovation	Linkages and networks	Transfer and adoption	Tertiary education and training	Institutional capacity creation	Regulatory including intellectual property	S&T information
Institutos tecnológicos	Recipients of support	Limited capacity due to scarce internal resources	Heavily involved, but capacity much criticized by academics	Involved in linkages to individual firms but formal networking still limited	A key function	Limited	Need to look carefully at their own capacities, capabilities, and competences	Some perform regulatory functions but overall regulatory system is under-developed; IP is a crucial issue; some institutes grappling with international changes in IP regimes (e.g. INIA)	Some provide information services to clients
Universities	Recipients of support	Not a function	Extensive research; growing involvement in technology development with firms	Most links to private sector are still weak; little tradition of networking	Some now recognize this function as important	Key role	Particularly necessary in many of the universities outside Santiago	Not a function; IP traditionally ignored, but some universities now see importance of IP	All seek to have staff publish, but few have supported patenting in past
New universities	Very little received	Not a function	Very limited, but beginning in a few cases	Limited	None to date	Key function, but question of standards	Need strengthening if they are to engage in research	Not a function	*Not discussed by review team*

(continued)

Table 4 concluded.

	Provision of financing		Performance			HRD And capacity building		Infrastructure	
Stakeholder	**Grant & contract support**	**Incentives (including tax incentives and use of purchasing power)**	**Research development and innovation**	**Linkages and networks**	**Transfer and adoption**	**Tertiary education and training**	**Institutional capacity creation**	**Regulatory including intellectual property**	**S&T information**
Private companies	Low investment	Would wish to receive a tax incentive for R&D	Probably more involved than widely appreciated	Very weak links to institutos tecnológicos and universities	Mainly from foreign suppliers	Limited interaction on training	*Not discussed by review team*	Some private-sector involvement in standards	Consumers of information
CODELCO	Funds external R&D	No information	Has major in-house R&D program	Some linkages	Strong function	Long tradition of extensive support	Developing its own in-house capacity	Not a role	a consumer of S&T information
Armed forces	*Not discussed by review team*	Not a role	Are responsible for three institutos tecnológicos	*Not discussed by review team*	*Not discussed by review team*	*Not discussed by review team*	*Not discussed by review team*	*Not discussed by review team*	*Not discussed by review team*
Advisory bodies	El Consejo Asesor Presidencial runs the Cátedras Presidenciales awards scheme	Not involved	Interested, to date, almost exclusively in basic research	Not involved	Not involved	Has not commented	Has not commented yet but believed interested in "Centres of Excellence"	Not involved	Not involved

Table 5. Institutos Tecnológicos and the implementation functions of Chile's NSI.

	Financing	Performance			HRD and capacity building		Infrastructure	
	Support to university research	**Research, development and innovation**	**Creation of linkages and networks**	**Transfer and adoption of technology**	**Tertiary education and training**	**Institutional capacity creation**	**Regulatory service provider**	**S&T information service provider**
INTEC	Does not itself finance external research	Yes, when supported by external funding	Key role	Key role	Not involved in formal education	Is involved in readjusting its own internal capacity following major staff reduction	No regulatory role but assists clients to meet environmental regulations	Yes
INFOR	Does not itself finance external research	Yes, when supported by external funding	Yes	Yes	Very limited	As with INTEC, INFOR is adjusting to effects of staff and budget reductions	Advises on forest management	Yes, including forest statistics
IFOP	Does not itself finance external research	Involved in aquaculture, in modelling of marine resources and in process improvement for fish-handling at sea and on land.	Seen as an important function	Key roles in aquaculture, in the development of new capture fisheries, and in improvement of technologies used in artisanal fisheries	Not involved in formal education	Has internally an unresolved duality in culture — part as technical support to a regulatory agency, part as promoter of technology development	Provides key technical input into regulation of marine fisheries	Yes

(continued)

Table 5 concluded.

	Financing	Performance			HRD and capacity building		Infrastructure	
	Support to university research	**Research, development and innovation**	**Creation of linkages and networks**	**Transfer and adoption of technology**	**Tertiary education and training**	**Institutional capacity creation**	**Regulatory service provider**	**S&T information service provider**
Fundación Chile	May subcontract from time-to-time	Yes, when supported by external funding	Key role; has a business-oriented approach	Key role; successful user of franchising and creator of new SMEs	Not involved in formal education	Creates and launches new companies based on improved technology	Not a function	Yes; provides significant services
INIA	Sometimes, but not frequent; INIA Staff compete with universities for grant funding	Yes; represents bulk of INIA activity	Has links, but only 4% of funding is direct from productive sector	Important element of INIA mandate	No funds for formal training in main INIA budget	Has received external support but did not include management training	No. Food safety done outside INIA	Yes
CIMM	Grants via FIM + contracts	Declining role	Some activity	Increasing emphasis	Extensive history of providing student training	*Not discussed by Mission*	No	Yes

Note: Due to necessary limitations in the Mission's interview schedule, twelve other publicly-financed "institutos tecnológicos" were not visited. These were:

- Centro de Información de Recursos Naturales (CIREN)
- Comisión Chilena de Energía Nuclear (COCHEN)
- Corporación Nacional Forestal (CONAF)
- Corporación Nacional Forestal (CONAF)
- Instituto Antártico Chileno (INACH)
- Instituto de Investigaciones Meteorológicas
- Instituto de Salud Pública
- Instituto Geográfico Militar
- Instituto Hidrográfico de la Armada
- Instituto Nacional de Hidráulica (INH)
- Instituto Nacional de Normalización
- Servicio Agrícola y Ganadero (SAG)
- Servicio Nacional de Geología y Minería (SERNAGEOMIN)

IV. Governmental processes for science, technology, and innovation policy formulation

In the industrialized world, through its Committee on Scientific and Technological Policy, (CSTP), the OECD has acted as a forum in which serious and valuable attempts are made to synthesize the best thinking on S&T policy of its member countries. Periodically, it challenges the established policies of member countries by permitting high-level groups of acknowledged leaders in thinking about S&T to look at future directions in S&T policy.

The Pigagnol Report (Science, Economic Growth and Government Policy, OECD, Paris, 1963) was the OECD's initial call to governments to take support of R&D seriously, since it recognized the relationship between scientific and technical activity and the dynamism of an economy. A year later, the CSTP published the "The Measurement of Scientific and Technical Activities," otherwise known as the Frascati Manual, (OECD 1964). This manual established the basis for measuring S&T activities within industrialized countries. This was the era in which the US National Academy of Sciences published its report entitled "Basic Research and National Goals" in 1965. In 1962, the scholar Michael Polanyi was also arguing his case for "The Republic of Science" in which he proposed that all decisions on the funding of science were to be made by active scientists. At this stage of early development of thinking on S&T policy, the major emphasis was on inputs to R&D. Policy concern focused on the financing of R&D, the availability of highly qualified people and of laboratory facilities, and on the roles of public institutions and programs.

Since the Pigagnol Report, at the rate of roughly once per decade, OECD has released major overviews of S&T policy thinking in the developed world. "Science, Growth and Society" (OECD 1971) captured the state of the debate on issues such as the integration of science policies with economic and social policies, and the role of multinational firms in technical progress. It asked how technological change was affecting the environment. By this time, concern for the difficult issue of measuring the outputs of R&D systems was becoming an increasingly important preoccupation. Next came the Delapalme Report (OECD 1980), which dealt in detail with the need for efforts to harmonize economic and technology policies. It asked how the member governments of OECD could:

> arrive at a synthesis of economic, technological and social adjustment policies which will optimize the contributions of technological development to economic and social development. (OECD 1980, pp. 5–6)

Both developed and developing countries are still searching for such a synthesis. At that point in time — in the early 1980s — the process of technological innovation was beginning to be recognized as a more appropriate focus of attention than simply looking at R&D per se.

Finally, most recently a major series of reports from the Council of OECD in 1990 entitled *Technology and Economic Policy* has situated thinking about technical change at the core of economic policy — even if many contemporary economists still have difficulty grasping the implications of this position.

The work at OECD leading up to *Technology and Economic Policy* was a stimulus to important efforts that sought to delineate the policy significance of the concept of NSI. Probably the most influential early publication on the subject was that edited by the Danish scholar, (Lundvall 1992).

Today, the industrialized countries have reached the conclusion that technical change is the principal driving force behind economic growth within their economies. Further, it is also understood that technical change has two primary sources — technological innovation and technology diffusion. This latter concept — technology diffusion — is crucially important and has embedded within it the need for technology recipients to participate in a continuing process of incremental innovation to adjust the acquired technology to the needs of the markets and supply systems of the technology user.

To oversimplify, think of the 1960s and early 1970s as the era of science policy, the late 1970s and 1980s as the era of S&T policies; and the 1990s as the era of science, technology and innovation policies. During these years there has been a global process of cumulative learning about the range of issues that need to be encompassed in the attempt to harness the forces of technological change to national economic and social development.

It was against such a backdrop that we attempted to evaluate the functions of Chile's NSI, beginning with the policy and resource allocation functions of the central government.

Chile has a variety of policies, programs and policy instruments dealing with aspects of scientific research, technological development and innovation, as well as technology diffusion. However, we were unable to identify a locus at the highest levels of government at which these policies were considered as a group — or at which the interaction of such policies with the other major policies of government might be analyzed or discussed.

In some countries, Ministries are designated that play a policy coordination role in the area of S&T while in others there are policy development offices established to advise Ministers. In each case, the particular modality chosen is selected to fit within the

particular political traditions of the country in question. As a result, for example, the modalities chosen in a parliamentary system of government tend to be different from those in a presidential system.

In theory, Chile has two bodies that might play such a role, but at present neither are particularly well-suited for it.

CONICYT still operates under a Decree (Ministerio de Educación 1971, Artículo 1, p. 1), which gives it broad responsibilities and functions, including:

> Article 1: The National Commission for Scientific and Technological Research is ...designed to advise the President of the Republic on the planning of scientific and technological development. It should develop, promote, and stimulate science and technology in Chile, and preferably orient them towards the economic and social development of the country. [Translation]

However, at the present time CONICYT is not structurally organized to provide advice. It has a significant enough task in managing several key financial instruments for the promotion of scientific research and technological development. A key decision, which has removed CONICYT's capacity to provide policy advice, was the decision to terminate the functioning of its Advisory Council. The present performance of CONICYT, and possible modifications to the way in which it operates, are discussed in some detail in the following chapter.

The other body is the Comisión Asesora Presidencial en Materias Científicas (Presidential Advisory Commission on Scientific Matters) whose principal function (Ministerio Secretaría General de la Presidencia 1995, Artículo 1, p. 1) is:

> To advise the President of the Republic on the identification of actions which would accelerate the coordinated and sustainable development of science in our country. [Translation]

This advisory body has terms of reference which limit its mandate to science, leaving out all reference to engineering or technology. In addition, it has few resources for a secretariat function, thus limiting its capacity to commission policy studies to underpin its discussions. During our meeting with representatives of this Comisión, we did not get the impression that it had as yet worked out any longer-term agenda of issues needing consideration.

We note that both CONICYT and the president's Advisory Commission have advisory and policy functions in their mandates and that both are engaged in the operational function of allocating resources. A responsibility for the allocation of resources requires an internal policy capacity. But the formulation of overall advice concerning system-wide policies for science, technology and innovation is considered, in

many countries, to present a conflict of interest situation. This is because of the larger number of players involved in funding and program operations across government.

We also appreciate the important role which CORFO has played in recent years both in the development of the set of funds now coordinated by the Programa Innovación Tecnológica and in the reformulation of government thinking with respect to the financing of public-sector technological institutes. We support the CORFO initiatives, including its efforts to have other line ministries provide multi-year performance contracts to technology institutes that are expected to perform public services. However, to underscore our point on a lack of a high-level mechanism, we ask how a dispute would be resolved if a ministry declined to engage in negotiation with CORFO and an institute on a performance contract? How does a CORFO policy on financing technology institutes become a Government of Chile policy? Has CORFO the right to seek cabinet endorsement of its initiatives, or would this be a role for the Ministry of Economic Development?

The Government of Chile should give serious consideration to providing itself with a mechanism to permit it to look at the full range of policies which it is implementing in order to harness technological change to the benefit of Chileans, and to ensure that the interaction of these policies with other policies of government is understood.

Chile has no functioning, high-level mechanism to examine broadly science, technology and innovation policies. Thus, it is not surprising that there is no discussion of the subject of a science budget — that is, of a means of displaying annually the proposed government expenditures relating to its science, technology and innovation policies. Such a management tool will become necessary if government at the highest levels decides to become more involved in these issues.

Financing mechanisms within the national system of innovation

V. CONICYT, FONDECYT, and FONDEF

CONICYT and the context for evaluating its main funding instruments

CONICYT was established by Law in 1968 and its duties defined by Decree in 1971. Since that time, has played an important role in the financing of scientific research and technological development in the country. It is generally viewed as a professional, committed, and transparent organization that has played an important role in strengthening the quality of Chilean research. Particularly broad support is given to its establishment of a criteria-based decision-making and funding system in 1981.

In its early years, CONICYT concentrated on support for investigator-driven research financed through FONDECYT, its initial major fund. In more recent times, two additional funding modes have been introduced that significantly extended the nature of research activities promoted, and the quality of the environment for research training in Chile. FONDEF, established in 1991, and FONDAP, launched in 1997, represent a recognition of the increasing importance of research to the economy and society, as well as the diverse types of research that must be supported through differentiated instruments.

Despite its track record, CONICYT remains the subject of sharply differing opinions among members of the Chile's S&T community. For example, the role of CONICYT and its funds in the overall Chilean system of S&T is seen by many of those whom we met as having been diminished or confused by two recent events:

1. the elimination of the CONICYT Executive Council; and
2. the establishment of a separate Advisory Council on Science and a President's Science Advisor who have the ear of the President and have become involved in a funding initiative that appears to have significant overlap with the CONICYT mandate — Las Cátedras Presidenciales.

There are sharply divided opinions on whether CONICYT has the authority and will to make strategic decisions in regard to larger public-policy issues, S&T or to the promotion of key fields and modalities of research that are important to Chile. Having CONICYT assume such a role and responsibility is viewed as critically important by many, but as dangerous by others.

Many of the issues and problems discussed in this report are intertwined with these outside the direct purview of CONICYT, including:

- the lack of an overarching government policy framework and coherence of structures for R&D, S&T and innovation;
- the culture of universities, institutes and the private sector — a culture that reinforces separation and different values, rather than converging interests and mutual interdependence of their futures (as in an effective NSI);
- the aging of university academic staff coupled with the lack of well-paid employment opportunities for the highly trained personnel who graduate from Chilean universities;
- the mechanism whereby universities in Chile receive their base funding and the behavioural implications of that mechanism (that is historical and inadequately linked with public policy and its purpose); and
- the overall funding level for S&T.

Even within this complex policy context, and even with a broad base of support for the professionalism of the CONICYT and its two main funds (FONDECYT and FONDEF), the CONICYT system needs significant change in order to serve an effective role in supporting knowledge activities of high quality and impact, along with an evolving system of innovation in Chile.

As a basis for discussing possible directions for change, we proceed now to our evaluation of CONICYT's major funds, which are discussed in the context of the four terms of reference established for the review:

1. the ability of the instruments to meet established objectives;
2. the performance of the instruments in assuring quality, relevance and sustainability;
3. the capacity of the instruments to respond to changing needs, opportunities and research paradigms; and
4. the adequacy of the resource base.

In the evaluation, particular attention is given to policies, programs or practices that are seen to induce adverse effects relating to key attributes of a fertile R&D environment. These include:

- ensuring there are opportunities for new researchers — both career prospects and research support;
- providing a more conducive environment to train students for and through research;
- expanding the interpretation of quality in research to promote multi-disciplinary research and long-range projects designed in the context of significant scientific challenges or real-world issues;

- promoting innovative research versus "safe" or incremental research (enhancing risk-taking that is the hallmark of innovation);
- fostering a broader, less self-referential, context for the evaluation of research excellence;
- enhancing the infrastructure for research to enhance individual and institutional research capacity, without which the purposes of public research cannot be achieved;
- increasing attention to research management and technology and innovation management, including strengthening institutional capacity;
- reducing the focus on monitoring and accountability based on financial control and intermediate outputs rather than long-range impacts;
- promoting independence and entrepreneurialism through programming flexibility;
- improving the management of intellectual property;
- increasing linkages among universities, technological institutes and the private sector;
- promoting purposeful approaches to regional development; and
- using judicious foresight in regard to the modalities and areas of research and research training that will best serve the long- and mid-range needs of Chile.

FONDECYT

FONDECYT — the National Fund for Scientific and Technological Development — was created under the umbrella of CONICYT in 1982. Its principal objective is financing scientific and technological research projects of a high level of excellence in all areas of knowledge, irrespective of the field or of the institution involved.

Its formal operations are carried out through two Superior Councils — one for science (7 members) and one for technological development (5 members). In turn, these are supported by 23 study groups made up of subject specialists in the various fields of research. Staff work is carried out by a FONDECYT administrative unit under the direction of an executive director (including the executive director, there are 23 staff), further supported by CONICYT staff (especially the Information Department and Accounting Unit). The president of CONICYT is a member of the Superior Council for Technological Development. The Superior Councils appear to function independently of any other formal linkage with CONICYT, except through the budget preparation process, and through "special initiatives" (see FONDAP, below).

In principle, a National Council carries out the allocation of funds for these two main streams of activities for Scientific and Technological Development comprising the Ministers of Education, Planning and Coordination, and Finance. In practice, this group

has met only twice in 17 years. In fact, during the last year the Superior Councils have taken a more active role in funding allocation — see below.

The principal functions of the two Superior Councils are to:

- establish research funding programs;
- announce competitions;
- allocate resources to programs and supervise their proper use;
- evaluate proposals;
- supervise committees established to assist with portions of the evaluation process;
- propose names of individuals to fill vacancies on the two Superior Councils; and
- monitor the management of the programs.

While formal responsibility for program delivery rests with two separate councils, they appear to operate as a "Council-of-the-whole", albeit primarily oriented to program administration issues. The routine workload of the combined Council is heavy. Meetings are held every two weeks for much of the year, with decisions on even the smallest administrative issue coming to the Council. There is very little delegation of authority to researchers, Study Groups or staff.

The FONDECYT program instruments are:

- projects funded through an annual competition (split into S&T streams);
- support for advanced study:
  - doctoral fellowships;
  - post-doctoral fellowships; and
  - thesis completion support;
- international cooperation;
- complementary lines — cooperative acquisition of research equipment; and
- FONDAP.

Of these the project instrument is the chief instrument and the one on which much of the reputation of FONDECYT rests. Table 6 outlines FONDECYT budget expenditures for 1998 — both competition and ongoing commitments.

The main FONDECYT program of project support operates through an annual competition for projects of 1–3 years' duration. Eligible applicants include individuals and institutions — universities and colleges, technical institutes, NGOs, and the private sector. In addition to Chilean nationals, foreign co-investigators are eligible, as are foreigners resident in Chile.

In 1998, FONDECYT instigated an *ex ante* resource allocation by discipline area, based largely on the allocation among disciplines in recent competitions. This modification in procedure was introduced as an efficiency measure and it is hoped that it

will encourage the study groups to scrutinize the requested budgets more carefully to optimize value for money.

Table 6. FONDECYT expenditure forecast, 1998.

	New awards		Commitments		Total expenditures	
Program	Number	Funding	Number	Funding	Number	Funding
Regular projects	359	5,993,938	543	7,287,262	902	13,281,200
FONDAP	0	0	2	1,200,000	2	1,200,000
Postdoctoral awards	23	325,914	21	285,347	44	611,261
Doctoral awards	44	194,132	70	339,688	114	533,820
Thesis completion	12	46,080	0	0	12	46,080
International cooperation	0	0	12	48,345	12	48,345
Complementary lines	0	0	7	442,119	7	442,119
Total	438	6,560,064	655	9,602,761	1,093	16,162,825

Source: CONICYT Panorama Científico, p. 23.

The 23-discipline Study Groups manage the major elements of the peer-review process. This includes examination of each proposal against basic eligibility requirements; assignment of each proposal to 3–4 external reviewers; assessment of the academic credentials of the applicants; scrutiny of the reports from external reviewers (and assessment as to whether to retain or recommend rejection of an external report); full merit review of a proposal if needed due to inadequate external reviews; and recommendation to the Superior Council of a rank-ordered list of fundable projects.

The peer-review process uses a point system, with points being allocated for:

- the research proposal — originality, clarity, theoretical and methodological foundations, bibliographic review and feasibility;
- the investigators — ability and experience of principal investigators and co-investigators, quality of previous publications;
- the viability of the proposed research — coherence between work plan and objectives, budget and results, and adequacy of the available facilities; and
- the relevance of the proposal — contribution to the development of new science or technologies, and contribution to the training of human resources for research.

As a recent change to the peer-review process, the Study Groups evaluate the academic and research credentials of investigators associated with each project on the basis of three parameters:

- scientific productivity (number of publications);
- quality of scientific productivity (impact factor of journals); and
- author's impact index, 1985–1995.

New instructions to the Study Groups ask that the applicants' age be considered as part of the review process of academic and research credentials to permit

identification of "young" researchers. The weight of this factor in the overall rating scheme was still under discussion at the time of our visit.

Project costs eligible for support through FONDECYT include:

- honoraria (or salary supplements), within prescribed limits, for principal investigators, co-investigators and other supporting staff, including students undertaking thesis work;
- travel and per diems;
- operating costs including routine supplies, computer services, lab analyses, bibliographic materials (but no furniture or routine administrative support);
- publication of results from the project financed by the grant;
- capital goods for equipment or instrumentation needed by the project, provided the one-time cost does not exceed US $38,000 FOB; and
- administrative costs not to exceed 17 percent of the total (guideline introduced in 1996).

Deviations from the original project objectives or expenditure pattern require review and approval by the FONDECYT Council (with the advice of the relevant Study Group). Annual reports are required and reviewed by the study group. Feedback is provided to about 20 percent of all funded projects. The majority of those comments relate to productivity.

Review term of reference 3A

Design effectiveness: ability of the instruments to meet their established objectives

The program objectives are broad. They are situated in the context of the CONICYT functions established in 1990, but without the context of a larger policy framework for the public support of long-range research and its role in society and the NSI. This compounds the problem of evaluation of effectiveness and accounts, in part, for the diversity of views that we heard in regard to FONDECYT's operation.

Overall, FONDECYT and its Superior Councils have significant support from the research community for professionalism, integrity and commitment. The FONDECYT programs have strengthened the Chilean capacity for research and instilled a culture of open dissemination of research through publications in refereed journals. However, the program delivery mechanism is unduly dominated by academic interests and a narrow disciplinary approach to research, to the extent that there are inadequate linkages between the processes of discovery and utilization of knowledge. In addition, the FONDECYT Council appears to believe that the larger policy matters and promotion of S&T are not, and should not be, within its mandate.

In 1997 the Dearing Commission's Report of the National Commission of Enquiry into Higher Education in the United Kingdom articulated four main roles for

university-based research and reasons for its public support. A modified formulation of these roles forms a useful framework for assessing the community opinions on the effectiveness of the FONDECYT activities in Chile.

1. Discovery — to advance knowledge and understanding.
2. Discovery in the context of utility — the generation of knowledge and inventions that support or contribute to wealth creation, environmental quality, the quality of life and public policy.
3. Enhancing the capacity for innovation — training people through and for research.
4. Informing and enhancing the quality of undergraduate education.

The stated objective of the FONDECYT programs of financing research "at a high level of excellence" could pertain to all four roles. While not explicitly stated, the program design appears to have given priority to the first and third roles, but we observe the lack of consistent views on the FONDECYT objectives, and some ambiguity of its relationship with FONDEF. It will be important for FONDECYT to revisit the its specific responsibilities in relation to these four roles.

We received a variety of comments from active researchers regarding the FONDECYT programs that provide a strong sense of direction for the future evolution of the programs. We heard that:

- There is an almost universal concern with the lack of new blood in the research community. Issues cited as contributing factors included: poor employment prospects for people with research training in all sectors of the economy; poor salaries in universities; serious difficulties experienced by new researchers in obtaining adequate support to initiate and sustain an independent program of investigation; and a lack of an S&T culture in Chile. Clearly, only some of these factors can be influenced by FONDECYT.
- The use of publications in ISI listed journals as a measure of productivity is controversial. Some argue that this has been a central force for improving the quality of Chilean science. Others argue that the attention given to this measure has led to:
  - a narrow interpretation of excellence (imposing the traditions of the physical sciences on other disciplines);
  - a bias against certain fields of research (geography, biosystematics, social and human sciences, engineering); and
  - a reinforcement of traditional modes of doing science while discouraging research targeted at social and economic problems and multi-disciplinary research groups.

A number of people interviewed believed that publication in national, regional and professional journals was appropriate but inadequately recognized.

- Some of the FONDECYT program elements and delivery mechanisms were seen to be in conflict with the objectives. Suggestions of the following actions are representative of the issues raised:
  - use of fewer Chilean reviewers to avoid parochialism;
  - redirect emphasis on achieving the forecasted project outputs to achieving significant research outcomes and impacts, in order to encourage high risk, innovative research;
  - increase predictability of renewal of FONDECYT awards when a high level of productivity has been maintained. At present the system has a randomness to it that ignores the cumulative nature of good research. An unwarranted gap in research support particularly disadvantages students and active new researchers who may have no alternative means of funding. A closer coupling of the research support with research training would be effective;
  - increase flexibility in administration to allow researchers to hold both FONDEF and FONDECYT awards simultaneously when they are for distinct research activities. The purposes of the two programs are substantially different, but since the activities being supported could be usefully complementary, sacrificing a FONDECYT grant on receipt of FONDEF support is considered counterproductive.
- Researchers in institutions outside Santiago consider that they face multiple and often insurmountable barriers in obtaining research support through FONDECYT, contrasting their success with applications under FONDEF. Issues cited were: lack of a strong institutional research tradition in some of the emerging institutions; inadequate research infrastructure, a more applied research orientation that is not encouraged by FONDECYT; and a lack of knowledge by Santiago-based peer reviewers of the quality of research carried out in regional universities.
- A number of the people interviewed expressed the view that there was a serious need for increased investment in research infrastructure, provided its acquisition is linked with active, ongoing programs and projects that have themselves been subject to expert review. Suggestions included incentives for the joint acquisition of infrastructure among universities and with external partners. The Complimentary Lines program is too narrowly targeted. In addition, developmental programs would allow regional institutions to become more competitive in priority areas of research activity.

- Increased funding for the FONDECYT programs is desirable, especially in the expectation that an increased number of new faculty members will have both the requisite training and the inclination for research.

Some of these issues are discussed in more detail below, with particular reference to international experiences. Issues relating to program efficiency are discussed in the following section.

The number of Chilean publications in ISI indexed journals was frequently cited as demonstration of the impact of the FONDECYT programs. Table 7 provides an overview of the evolution of publication patterns in Chile from 1981 when the criterion-based, output-oriented review system was established. Publications per capita of population have increased by about 50 percent over this time; the number of publications per investigator year has remained relatively constant.

Table 7. Bibliometrics — publications from Chilean researchers.

Year	ISI listed publications	Publications/ 1,000,000 population	Number of investigators	Publications per investigator
1981	675	5.96	3,420	0.20
1982	655	5.75	3,547	0.18
1983	827	6.97	3,727	0.22
1984	707	5.86	3,886	0.18
1985	768	6.25	4,079	0.19
1986	865	6.95	4,251	0.20
1987	857	6.78	4,588	0.18
1988	934	7.18	4,803	0.19
1989	991	7.49	5,115	0.19
1990	1,112	8.37	5,421	0.20
1991	1,157	8.45	5,628	0.20
1992	1,244	8.90	5,860	0.21
1993	1,275	9.11	6,028	0.21
1994	1,255	8.78	6,223	0.20
1995	1,403	9.70	6,388	0.22
1996	1,489	—	6,619	0.23

Source: CONICYT.

The use of publication numbers, and citation counts, has some validity as an after-the-fact monitor of certain types of research activity across discipline areas. However, the use of bibliometrics at the national level masks legitimate variations among fields or disciplines of research. More importantly, it mitigates against recognizing major gaps in fields or specific types of research that have very different publication characteristics, but with particular resonance with national needs. They also say little about the effectiveness in promoting an environment for research training, the social and economic value of the research and the extent to which undergraduate

instruction has been enriched by the research activity — some of the key roles of publicly supported research. Finally, they say little about the societal outcomes of that investment. We would also note with concern that the data in Table 7 imply that the average Chilean researcher produces only about one publication every five years. In almost all fields, this constitutes a very low rate.

The insistence on rapid publication of the results of FONDECYT-supported research can be a disincentive to innovation in those cases in which a piece of work gives rise to patentable results. Patent Offices will not give protection to ideas which are already in the public domain.

As nations recognize the importance of S&T and innovation in economic development, increasingly they are moving from single indicators to more complex, multiple systems of measurement that link directly to the broader societal context, and within that the public policy goals of the national S&T system. A recent publication from Statistics Canada (1997, p.2) notes that:

> To give S&T indicators some coherence and meaning beyond what they represent, they must be fitted into a structure... or framework. The framework is a model of S&T knowledge creation and use and it contains two components: the S&T system, and the society and the economy of which the S&T system is an integral part.
>
> For years there was a simple policy framework ...It was based on the belief that support for R&D led to an enriched stock of ideas and eventually to higher productivity and economic growth...
>
> Public support for R&D and S&T will increasingly rely upon the ability to demonstrate the positive social, economic and environmental effects for society as a whole, that result from S&T activities.

Excellence, therefore takes on a wider meaning in relation to both the evolving nature of research as well as societal expectations and needs. Measures of national research productivity should not obscure a broader context for assessment of outcomes.

We were surprised to learn of one FONDECYT policy — that which requires repayment in full of a FONDECYT grant when the project financed is deemed to have failed to meet its stated objectives. The FONDECYT Council might debate the effect of this provision on the propensity of the research community to undertake high-risk ventures in new directions. Is the threat of having to repay a disincentive for innovative approaches? Our concern is not for the case in which a recipient simply does not use the grant for research; in such cases, repayment seems appropriate. Rather, it is for the way in which the criteria for requiring repayment may be defined.

In 1994, a widely read book, The New Production of Knowledge, (Gibbons et al 1994) suggested that we are experiencing a transformation — or at the very least a transition — in how knowledge is generated, stored, transmitted and used. This change includes transformations in the motivations, operation and organization of knowledge in institutions and their relationships with society. Inasmuch as the hypothesis is accepted, it implies very different instruments for its promotion and evaluation. We believe that this hypothesis merits discussion in Chile by institutions and FONDECYT alike.

The book's authors suggest that the emerging mode of research that will not supplant, but will compliment more traditional investigation is characterized as:

- operating within a context of application — problems and issues are defined and research organized in response to a particular context or application that is articulated outside the discipline or field of research;
- exhibiting trans-disciplinary characteristics — the research conceptualization and methodology goes beyond the cognitive and social norms for any one discipline;
- possessing heterogeneity and organizational diversity — the research team requires a diversity of skills and experience that change over time and in response to the evolving research requirements; and
- having social sensitivity and accountability — inclusion of social considerations in setting the research policy agenda and the decision-making and performance evaluation process — that is, social values influence research directions.

The most important consequence is that this mode of research requires new approaches to quality assessment and performance measurement. Many believe that it requires rethinking the traditional discipline peer review system that moderates decisions on who is qualified to do research, and what research is carried out. As well, the effective review system would incorporate a wider range of context expertise and appropriately broadened criteria (market or policy relevance and social acceptability). Similarly, indicators of performance are broader.

The FONDAP initiative provides a very large-scale test-bed for research of this type, but the question remains as to whether the design of the FONDECYT project instrument provides adequate scope for the evolution of ideas for future FONDAP initiatives.

FONDECYT and the need to attract new people into research

During our discussions with the community, one issue dominated — how to attract and retain outstanding research talent in Chile. We were struck by the extent of concern for the ageing of the research community and with new means of facilitating the entry of the next generation of researchers in Chile. The problem is real, as evidenced by Table 8.

Table 8. Demographics of principal investigators in 1998 competition.

Age group	Applicants			Awards			Success rate		
	Total	M	F	Total	M	F	Total	M	F
<35	67	52	15	16	15	1	23.9	28.80	6.70
35–44	383	302	81	119	96	23	31.1	31.10	28.40
45–54	413	280	133	122	95	27	29.5	33.90	20.30
55–64	243	187	56	80	62	18	32.9	33.20	32.10
>65	35	29	6	8	5	3	22.9	17.20	50.00
Total	**1,141**	**850**	**291**	**345**	**273**	**72**			

There are relatively few researchers under the age of 35 and the success rate for all age groups, notably this one — and particularly for women — is poor. The problems cannot be tackled by FONDECYT or even CONICYT alone, but we discussed the issues and possible role of CONICYT/FONDECYT with many of the people interviewed. Six particular aspects of the human resource "pipeline" received attention:

1. interesting young people in a career in research;
2. providing adequate support for graduate studies (through both individual student fellowships and the support of projects on which the student works);
3. providing opportunities for post-doctoral studies (particularly with an international component that will introduce the student to a broader learning experience);
4. attracting outstanding candidates for new faculty positions;
5. providing adequate opportunities for research support to new researchers; and
6. improving the prospects for private-sector employment of individuals trained through research.

The value to a research trainee of combining experience in Chile and offshore was reiterated many times in our discussions. An expanded program of support for research training through to the post-doctoral level was frequently proposed. In this context, many of those interviewed expressed concern with the lack of cohesion in strategy and evaluation standards represented by the distribution of the various programs supporting research training among different agencies:

- the FONDECYT programs supporting postgraduate studies (PGS) and post-doctoral fellowships (PDF) in Chile;
- the program of PGS awards tenable outside Chile managed through the Ministerio de Planificación y Cooperación; and
- the program of PDF awards abroad managed by CONICYT.

The success of a more aggressive program of student and postdoctoral training will need reassessment of the present instruments used.

The problem in new faculty appointments is multifaceted. In the current tight-funding regime and the age distribution of faculty, institutions report that they have difficulty committing themselves to hiring new staff. The lack of alternative employment opportunities in the private sector decreases the pool of research talent in Chile, requiring recruitment of Chileans abroad. Non-competitive salary levels, especially in fields other than the natural sciences (law, medicine), encourage part-time faculty who substitute professional practice for the research function. The intense competition for research funds adds to this mix of disincentives. While not explored in great detail, interest was expressed in providing incentive funds for bridging positions (to a point where an institution could assume the normal responsibility for salaries).

Many felt that there was a need to have a special competition for project support open only to new researchers, a sort of "affirmative action" program. This would entail competition among new researchers, but not set up a new researcher in face-to-face competition with a former supervisor and advisors. Flexibility in application procedures (for instance, no fixed deadline) would be a real asset in hiring, so that the new researcher could access the funds on arrival and immediately commence work.

Many countries have introduced programs for the support of research projects and bridging salary support for new researchers with considerable success. Salary support programs are normally time-limited and designed to tackle clearly identified problems. The New Blood scheme in the UK, and the Canadian University Research Fellowship and the Women's Faculty Award programs are examples of this. Incentives for new researchers are also very common, with a 3–5 year proving period built into the evaluation system.

We believe that research training can and should equip an individual for a variety of career pathways, not simply an academic track. The skills and competencies gained through training in research should provide an individual with a capacity in advanced analysis and the ability to solve complex problems. When the private sector appreciates the benefits of tapping into this competence and knowledge base, the flow of researchers into universities will be improved, simply by virtue of a better demand for their outputs in the private sector: people and knowledge. As such, actions on the supply side will be important, but of restricted scope.

Regional and institutional distribution of FONDECYT awards

Data provided by CONICYT indicate that in the 1998 competitions, 69 percent of FONDECYT's funds were directed to researchers at three universities in Santiago. The funding rate for applications from these three institutions was 34.6 percent, as compared with an 18 percent funding rate for all other universities (other institutions were excluded from this analysis; for reference their funding rate was 26.9 percent, and their

share of the total FONDECYT expenditure 6 percent). Without prejudice as to the quality of the applications from outside the three reference institutions in Santiago, and to their ongoing research activity, this intense concentration of research activity and resource deployment represents a serious problem. While faculty numbers for all institutions were not available to the Mission, these three universities represent only 20 percent of the faculty in the sector containing the 25 state-supported higher-education institutions. No comparative data on the state of research infrastructure were available to the Mission, but representations from some of the research communities interviewed indicated the significance of this element in their competitiveness for FONDECYT funds

Distribution of R&D performing entities is important for the functioning of an effective system of innovation. For Chile, where distances between regions are great and economic activities are differentiated among regions of a country, proximity to universities with a strategic orientation aligned with regional interests can be a significant asset.

We heard from a wide diversity of regional universities and institutions. Some have a well-developed and managed research infrastructure. Others are much more embryonic in their development of research capability and strategy, but serious in intent. Those who met with us expressed a firm commitment to embedding research as a central element of the institution's long-range strategy. They considered improved access to FONDECYT programs as essential.

Review term of reference 3B

Performance efficiency and effectiveness: assurance of quality, relevance, and sustainability

We received comments from researchers, university administrators and FONDECYT officials concerning the processes used to assess quality and to allocate resources among competing projects. Overall the program administration is seen as being transparent and honest, with a consistency of approach that was admirable. At the same time, a number of problem areas were identified regarding:

- the system of external reviewers;
- the emphasis on publication counts;
- the need for more predictability; and
- the agreement for administrative flexibility.

In regard to the system of external reviewers, many of those interacting with us identified the dominance of Chilean reviewers in some disciplines as problematic. While we have not had the opportunity to verify the claims, it found compelling the number of individuals who stressed the advantages of having a minimum of two reviewers from outside Chile to ensure benchmarking of Chilean research against international norms.

They also expressed concern with the self-referential nature of some evaluations. We were advised that current practice involved the following:

- in mathematics, physics and earth sciences all but one reviewer may be foreign (the new policy requires one to be Chilean);
- the disciplines of engineering, chemistry, biology traditionally use a mixture of foreign and Chilean reviewers; and
- in all other areas there is a tendency to use Chilean referees (social sciences, medicine, history, education).

The peer review systems of other nations of comparable size tend to use a minimum of 1–3 non-national reviewers, with particular care to ensure that areas of national interest have some national reviewers. Traditionally, the social sciences tend to be more difficult to cover through the mix of national and international reviewers. Thus, a stronger Study Group may be required.

Concern with the emphasis on publication counts at the level of the individual researcher was another recurrent theme in our discussions, with a diversity of comments on the nature of the problem and the desired solution. Generally there was a consensus on the need for an emphasis on achieving significant research outcomes; the need to encourage high-risk, innovative research; and the fact that the current preoccupation with numbers of publications discouraged both these points.

Bibliometrics have some validity for international comparisons of specific fields at a high level of aggregation, but they are not suitable for evaluation at the level of the individual scientist. We are concerned that the use of publication and citation counts and impact factors may obscure the real-life impact and quality of research activity. We also note that such publication counts are best used in conjunction with other quantitative measures (multiple indicators) and qualitative assessments.

The FONDECYT program was viewed by a significant portion of the discussants to be a lottery in which chance and the financial fortunes of FONDECYT — rather than demonstrated capability and project potential — determined the fate of an application for support. Even a strong application would not guarantee support. Researchers observed that the capacity for research and research training is cumulative. Breaks in research support disadvantages students and active new researchers who may have no alternative means of funding. A closer coupling of the research support with research training would be effective.

There were a number of calls for increased administrative flexibility, including the flexibility to allow researchers to hold both FONDEF and FONDECYT awards simultaneously when they are for distinct research activities. Again we repeat that this rule creates an unnecessary barrier between knowledge generation and its potential application.

The application process for a FONDECYT grant involves activities and timeframe listed in Table 9.

Table 9. Timeframe for FONDECYT grant approval process.

Activity	Elapsed time
From program announcement to receipt of applications	2 months
From receipt of application to official notification of decision; operation of the academic evaluation process	7 months
From official notification to signing of contract	1–2 months
From contract signing to release of funds	Within 1 month
Overall process from receipt of application to release of funds	9–10 months

The program is managed on an operational cost of 1.94 percent of the total resources administered, including stipends for the work of the academic evaluation system, and charge backs for access to CONICYT's support staff. Elimination of the stipends paid to the Study Group and Council members decreases the overhead rate to 1.53 percent.

We observe that this administrative overhead is exceedingly low by international comparisons. In Canada the Natural Sciences and Engineering Research Council operates with an overhead of about 4 percent of the funds administered, without any stipends being paid to members of its committee structure. That Canadian agency is generally considered to be a very lean and efficient operational entity. In comparison, FONDECYT is positively skeletal.

This low overhead, coupled with the burden of routine administration of funds that is carried out through a process involving the staff and the full FONDECYT academic evaluation system (see below), may explain, in some measure, the length of time taken for the process to run its course to the release of funds. Other countries have managed to reduce the elapsed time of a comparable process, involving external peer review by international experts and subsequent disciplinary review, to about 5–6 months. In discussions with the FONDECYT staff, we reviewed international trends towards greater delegation of authority in program administration. In addition, we explored several options for reducing the administration burdens on staff, and potentially reducing the time to release of funds. These are summarized below in order to stimulate further discussion.

1. Delegation to researchers

Under the current regulations, recipients of funds are required to submit an annual progress report that is reviewed by the academic evaluation system, with feedback provided where issues are identified. In addition, modifications in budget, project goals,

and the composition of the research team are required to be submitted to FONDECYT for review, once again through the full academic evaluation system.

We observe that in many countries there is a move to provide more operational freedom to researchers during the tenure of an award through delegation of increased levels of authority for operational decisions, as a quid pro quo for substantive accountability (for demonstrating outputs and impact) at the end of the funding period. This is also designed to promote the freedom for risk-taking that is the hallmark of innovative research. Routine financial reports are required during the tenure of an award, but the substantive report on outputs and outcomes is required only at the end of a 3–5 year award. Considerable administrative efficiency should be possible with some moves in this direction.

We were advised that about 20 percent of the annual reports result in feedback to applicants, primarily on productivity. FONDECYT might wish to explore other means of ensuring a high level of awareness about the importance of dissemination of research results.

2. Delegation to study groups

We were advised of the heavy meeting schedule of the Superior Councils (every two weeks) and the lack of time to consider policy issues. There has been a recent change to assign ex ante allocations to the Study Groups, along with a possible re-examination of the authority delegated to researchers. These changes offer scope for a significant shift in the nature and intensity of the workload assumed by the Superior Councils. In addition, a less onerous meeting schedule would make it easier for researchers from the regions to participate actively in the work of the Superior Councils.

3. Delegation to CONICYT staff

At present, the staff workload is dominated by serving the routine program administration needs of the Study Groups, Superior Councils and the research community. We observe that in other countries, the staff complement assumes responsibility for many routine decisions that are currently taken to the Study Groups and even to the Council for decision, and suggests that further efficiencies are possible. Of more importance, a realignment of responsibilities among researchers, the academic evaluation system and staff could free-up time for program evaluation and an assessment of outcomes and impacts.

Review term of reference 3C

Evolutionary capacity: ability to respond to changing needs, opportunities and research paradigms

Our impression of FONDECYT is that it has provided a credible and useful program structure that has the virtues and constraints of consistency. There have been only incremental changes in the core program areas until recent years, when a new program, FONDAP, was introduced. This action was chosen rather than making a fundamental change to the existing project program. The FONDECYT Superior Councils noted there was no explicit mandate to take an active role in the development and promotion of S&T, and that other program initiatives were limited by the lack of resources. We note additional limitations in regard to an adequate staff infrastructure and a governance structure that more adequately represents the diverse stakeholder communities.

In response to questions, members of the FONDECYT Superior Council reflected that the discipline coverage of the programs was unlikely to have changed markedly over time, except for the addition of FONDAP. Examining the data on the number of projects supported since 1982 reveals that while this is generally true, there has been a shift in recent years (see Table 10). The proportion of projects awarded in the social sciences and humanities have increased, those in the more applied areas of engineering, medicine, agriculture, forestry, and related technologies have decreased. Consistent with comments from the research community, the mission speculated that the availability of larger project funds in applied sciences through FONDEF may have decreased FONDECYT

Table 10. Evolution of discipline coverage at FONDECYT.

	1982–1995 % projects	1996–1998 % projects
Mathematics	5.6%	7.0%
Physics	4.7%	5.6%
Chemistry	6.8%	6.1%
Biology	17.5%	15.7%
Earth sciences	3.4%	3.2%
Astronomy	1.7%	1.3%
Sub-Total	*39.5%*	*38.9%*
Engineering sciences and technology	15.5%	12.6%
Medical sciences and technology	13.8%	12.9%
Agricultural and forestry sciences and technology	8.8%	8.5%
Sub-total	*38.1%*	*34.0%*
Social sciences	11.0%	11.4%
Legal, economic and administrative sciences	4.2%	5.2%
Humanities and fine arts	7.3%	10.4%
Sub-total	*22.5%*	*27.0%*
Grand total	**100%**	**100%**

demand in these fields. Whatever the cause, there would appear to be a need for some overall policy thinking about the evolution of FONDECYT support and its relationship with FONDEF.

The most dramatic programming change within the scope of FONDECYT is FONDAP — a mechanism that sparked strong reactions in the community. This is primarily, but not uniquely, because of negative perceptions concerning its origins, evaluation mechanisms, and independence from intervention. We believe that, regardless of the merits of FONDAP's initiative, it is critically important to encourage more extensive dissemination of information on the program and transparency of action within it than appears to exist today.

We were informed that the origins of FONDAP lie in the report of a committee appointed in the late 1980s by the then President of CONICYT to investigate instruments to promote the evolution and future directions of long-range, basic science. The outcomes of the committee deliberations included proposals for two new instruments. Among them was the model for FONDAP — a program that would foster concentrations of research based on two criteria:

- the existence of a critical mass of high-quality researchers in an area; and
- the relationship of that area to national development.

The result was a proposal for a new initiative focused on large-scale research. Ten areas were defined, of which two were selected in conjunction with the Minister for the initial round of FONDAP grants initiated under the auspices of FONDECYT.

Despite the controversy surrounding its birth, FONDAP represents a dramatic step in the evolution of long-range research in Chile. We cannot fail to notice the close alignment of the FONDAP objectives with the characteristics of the evolving and important modes of research identified earlier. The program has the potential to catalyze research that bridges the boundaries between traditional fields of investigation, by virtue of its focus on research themes, rather than disciplines, and the active encouragement of groups of researchers working in an international context. At the same time, we must observe that there appears to be significantly more concern with the process of creating and managing the program than the long-range policy implications of its existence. We believe that it is important to turn policy attention to the opportunities within the FONDAP mechanism to support and promote leading-edge research and research collaborations that go well beyond the types of activities possible within regular FONDECYT programs.

International experience is that major changes in research and funding modalities rarely happen from within existing programs; rather the instigation of new programs and modalities of support trigger them. We also note that it is generally healthy for a country to have multiple modes of research support with complementary objectives, proving that

there are clear program objectives set in a larger policy framework and a mechanism for assessing achievement of the objectives and re-balancing of allocations as necessary.

Review term of reference 3D

Funding sufficiency: adequacy of the resource base

The research funding and administrative resource base are discussed separately.

Beyond issues relating to the distribution of the current budget, there is widespread concern that the funding base of FONDECYT is inadequate for future needs. Assessing the pressure on FONDECYT resources is non-trivial, however. The adequacy of the current base and future funding prospects will be influenced by how FONDECYT's role evolves in a changing portfolio of research-funding instruments (such as its role relative to FONDEF) and the economic strategies and health of Chile. The question that Chile must answer is whether, in relation to the contribution of S&T to its socioeconomic development, the infrastructure for long-range research and research training is adequate.

We observe that the decrease in the competition success rate over the last decade may be indicative of a growing problem, given that the new faculty appointments are generally selected with a strong track record in research. Perceptions that new faculty find it difficult to launch an independent FONDECYT project are reported to be affecting registered demand. With a limitation on the cost of equipment that can be purchased from FONDECYT grants, no meaningful estimate can be obtained of unmet demand or extent of need for instrumentation.

The financing of infrastructure and major equipment is an issue needing some thought within CONICYT. FONDEF, which is discussed in the following section, is one of the few Chilean sources of financing of research infrastructure and of major pieces of equipment in the universities. As well, FONDEF is based on industry partnership with the university in specific projects. This means that identifiable industrial interests have a major role in determining what research infrastructure will be established or updated in the universities. This is a reasonable proposition for the applied sciences. But relying solely on this approach could be a serious disadvantage to some basic, very exploratory research. Such research could be essential to sustained science excellence — but much of this is too risky for individual firms to help fund. Thus, it may be necessary for FONDECYT to play a greater role in funding major equipment and infrastructure for basic studies, precisely because this is its area of emphasis.

A significant issue is the use of FONDECYT funds for salary supplements. At present just over 25 percent of project costs are dedicated to salary supplements, funds that are then unavailable for other project costs. These supplements are widely supported by the community, primarily because of the low base-salary levels in universities. Note

that very few people interviewed referred to the supplement as a particularly important incentive for research. While we acknowledged the validity of faculty salary expectations, we were concerned that the presence of salary supplements provides a means of avoiding tackling the source problems — financing of the overall university system, salary structures and definition of institutional roles in research (including differentiation of research roles). The same comments apply to FONDEF, where an even higher share of project budgets may be applied to salary supplements — the higher share being a consequence of the larger groups of researchers involved.

Decisions on the FONDECYT resource base cannot be isolated from the directions of a larger S&T strategy for Chile and the evolution in program policy and design within that context, including the future role FONDECYT in relation to FONDEF. Even within this context, however, our view is that new strategies and funding levels for the next generation of researchers will be a priority call on new resources for FONDECYT. Attention to the state of research equipment is also needed, and we note the value of integrating decisions on equipment resource allocation with funded projects, research training, and of encouraging partnerships in funding, management and exploitation. Finally, we consider that the orderly evolution of the FONDAP modality for funding long-range research is critically important for the research and research-training culture and capacity in Chile.

Effective management of a changing portfolio of programs within FONDECYT will require a strong staff underpinning to a revised program-governance structure. Redesign of the program administration will provide some of the needed resources, but not all. We observed that few charities run on an overhead as low as that of the FONDECYT programs. FONDAP has introduced a new approach to program management that integrates external and internal functions; the core FONDECYT activities may offer some comparable opportunities.

FONDEF

FONDEF was founded in 1991 as a direct result of an initiative of the Government of Chile acting in close association with the Inter-American Development Bank (IDB). In 1992, its administration was assigned to CONICYT, although it also falls within the group of programs under the policy umbrella of PIT (Programa Innovación Tecnológica, Ministerio de Economía)[3].

FONDEF was designed to provide a means of enhancing R&D related to national needs, while retaining a strong commitment to open market forces and the belief that governments cannot pick winners. At the time of its initiation, government recognized

[3] Six funds form part of the PIT envelope: FONTEC, FONDEF, FDI, FIA, FIM, and FIP.

inadequacies in the S&T capacity in universities and technological institutes, as well as the positive externalities in public support of programs and projects

FONDEF's mission is to strengthen and help to improve the capacity for scientific and technological innovation of national R&D institutions, by financing projects with high quality, significance and impact in order to improve the productivity and competitiveness of the principal sectors of the economy. Three specific objectives guide its operations.

1. To increase the quality and quantity of R&D and the provision of scientific services with a significant impact on productive activity.
2. To facilitate the transfer of knowledge and know-how to the productive sector through collaborative activities between R&D performers and business.
3. To increase the concentration of R&D activities in areas of high priority and which offer both social return and a contribution to the national interest.

In its initial period of existence, FONDEF supported research in six defined priority areas: agro-industry, forestry, informatics, manufacturing, mining, and fisheries (including aquaculture).

Originally FONDEF isolated six priority areas for research. Recently however, these were expanded to nine research areas. The original six areas were comprised of four natural resource fields (fisheries, agro-industry, forestry, mining), manufacturing industry and information technologies, including telecommunications. The new areas are ones in which the market has strong social as well as economic components: water and energy management, health, and education (innovation in higher education).

Institutional eligibility

FONDEF support is open to:

- universities;
- technological institutions;
- other non-profit R&D entities;
- consortia of eligible institutions, including consortia with companies as partners; and
- the private sector.

All projects require a 20 percent contribution from the private sector and evidence of effective collaboration.

Internal structure

FONDEF is managed by an Executive Director under the auspices of a Board of Directors, all members of which, at present, are drawn from the public sector.

The FONDEF program instruments are:

- R&D projects oriented toward innovative processes, new products and services or other technological innovations;
- technology transfer projects; and
- technological infrastructure projects in priority areas.

Competitions for FONDEF funds have not been held on an annual basis, but at intervals based on the availability of funding. Table 11 provides an overview of the results of FONDEF competitions since the initiation of the program in 1992.

Table 11. FONDEF expenditures (current-year pesos).

Year	New projects funding (pesos)	Number of new projects	Ongoing commitments funding (pesos)	Total expenditures (pesos)
1992	66,266,160	53	N/A	
1993	395,231,166	46	5.839,199,857	6,234,431,023
1994	N/A	0	8,960,346,943	8,960,346,943
1995	131,114,000	78	5,595,839,069	5,726,953,069
1996	2,384,750,000	60	2,599,397,390	4,894,147,390
1997	2,856,761,245	47	2,893,735,067	5,750,496,312
1998	2,449,678,379	65	3,098,307,226	5,547,985,605

Project review process

Projects are evaluated on two prime criteria: scientific or technological quality and expected socioeconomic benefits

For each field there is an expert committee of 3–5 persons (researchers, professors, company managers) charged with assigning the science and technology external reviewers to each project under assessment. In normal practice, 90 percent of the reviewers are Chilean and two are assigned per project. Issues considered in the assignment of reviewers include: knowledge base, lack of conflict of interest, past record on evaluations. Evaluators are paid.

Some 50–70 questions are asked of each evaluator in each of three chapters regarding:

- quality of the idea (originality, creativity, feasibility);
- management — a demonstrated ability to develop, manage and deliver; and
- transfer of technology (usually the weakest component).

The expert committee reviews the proposal on the basis of the external reports. If there is a serious conflict between the two reviewers, a process of arbitration may be invoked.

Each question has an assigned weight. The proposal is scored on a scale of 0-100 percent, with the following rating scale:

- >75 percent = very good;
- >60 percent = good; or
- <50 percent = insufficient quality to merit funding.

The socioeconomic evaluation is done by a group of eight staff people experienced in socioeconomic and engineering assessments. They look at investment, return on investment, and cost in order to rate the potential value added.

The scores are then plotted on a matrix of quality versus benefits, with the outcome of this exercise going to the FONDEF Board. At that level, the institutional impact is examined. Other issues, such as eligibility and environmental impact, are considered at the staff level. The budget is evaluated versus needs; proposed budgets are usually somewhat decreased.

Since its inception (and up to the end of 1997), FONDEF funded 271 projects in eight areas (plus one multi-disciplinary area). Higher education has recently been added as a new theme area, but no awards were made prior to 1998. The distribution of awards and funding are shown in Table 12.

Table 12. Sectoral data on FONDEF projects.

	Projects 1992–1997		Project funding		Average project cost
Sector	**Number**	**% of total**	**US $000**	**% of funding**	**US $000**
Agriculture	58	21.4%	56,712.4	20.1%	977.8
Energy	3	1.1%	4,360.8	1.5%	1,453.6
Forestry	47	17.3%	52,334.5	18.5%	1,113.5
Information technology	14	5.2%	24,011.4	8.5%	1,715.1
Manufacturing	30	11.1%	22,722.0	8.0%	757.4
Mining	70	25.8%	52,990.0	18.7%	757.0
Multi-area	6	2.2%	19,320.0	6.8%	3,220.0
Fisheries	36	13.3%	43,740.0	15.5%	1,215.0
Health	7	2.6%	6,474.3	2.3%	924.9
Total	**271**	**100.0%**	**282,680.1**	**100.0%**	**1,043.1**

Review term of reference 3A

Design effectiveness: ability of the instruments to meet their established objectives

FONDEF has been operating for less than a decade, and has funded only 271 projects up to the end of fiscal year 1997. Even with this limited operational experience, the program has had a significant impact. In its wide-ranging discussions with both the research and business community on the FONDEF program mechanisms, we heard that:

- FONDEF has helped to improve the relationships between universities and institutes as well as industry and to promote industrially relevant research. Since the onset of the program, project proposals have improved, and there have been noticeable shifts in university R&D culture.
- The overall success of the program is limited by the lack of an innovation culture in both industry and university, and a concurrent lack of respect for the potential returns from intellectual property. The lack of understanding of the innovation chain (idea to research to product to marketing) is a problem for both universities and companies. However, this is not something that FONDEF can tackle alone.
- There is an additional problem in industry: a lack of capability in technology management. Training in technology management is vital and is one of the most important spin-offs from FONDEF projects. But FONDEF could also take a more active role in promoting the development of such a capacity within the universities and institutes through its programs.
- FONDEF funding does not normally take a product, process or service to market. Other funding mechanisms and steps are required, especially relating to market awareness and marketing. The linkages between FONDEF funding and next stage financing are not yet well developed.
- Some believe that the program would be better targeted to needs explicitly articulated by industry, and require a greater financial commitment from them. Others are concerned that universities should not be seen as a substitute for the appropriate role of industry in market awareness and commercialization, and that additional financial commitments from an evolving private sector would be unrealistic.
- There is an important regional dimension to FONDEF. If deficiencies are flagged, a repeat application that entails an alliance designed to overcome the weakness will often be successful. Regional governments often support FONDEF applications with their regional funds.

During its lifetime, there has been accumulating evidence that FONDEF makes three main contributions:

1. Improvement in resource-allocation procedures, by initiating competition for funding of larger projects that are designed to have both a technical and institution-strengthening impact. This has affected both the efficiency and transparency of the grant-giving process. We believe that there can be merit in direct allocations to universities, especially for supporting research infrastructure and graduate-student training, provided that there is some widely understood and accepted basis on which to make those allocations. However, as we note elsewhere in this report, the present system of financing universities is still not well geared to serving public policy purposes.

2. Changes in the attitude and way of participation of researchers and other professionals in universities and other institutions. These changes can be seen, for instance, in several ways.
   - The larger size and increasing complexity of projects that have provoked new ways of project management and organization (such as multi-disciplinary teams, designation of project directors with managerial skills).
   - Improved linkage of institutions with companies, going from the almost complete absence of formal or explicit linking about ten years ago, to the present situation in which a small but growing number of companies participate both by identifying problems and research opportunities, and by contributing resources and personnel. However, this participation is still far from uniform and varies significantly among economic sectors, institutions and companies.
   - Valuable opportunities for university students to participate in FONDEF projects and to experience a research environment that are influenced by the needs and interests of the private sector.
   - An improved recognition among growing groups of researchers and institutions, who recognize the value of research that is targeted to the economic and social interests and needs of the private sector and of the government as client. Additionally, the program has demonstrated the synergy of application and discovery.
3. Contribution to a better balance of resource allocation and project selection among institutions from different regions of the country. Today, almost 50 percent of resources are assigned to regional institutions on a competitive basis, which is far better than the nearly 30 percent of 7 years ago. This has been possible because institutions are learning how to define and develop the main fields in which they want to be stronger and more competitive, as well as how to overcome weaknesses through alliances.

While in none of the above cases would we conclude that all problems have been solved, we recognize the existence of a continuous pattern of improvement.

An analysis by FONDEF management also reflects the limitations of the program in achieving its economic objectives. We were advised that of the outputs of completed FONDEF projects:

- ~20 percent get to market;
- ~10–20 percent seek FONTEC support (or equivalent) as a means of moving the output closer to commercialization; and
- ~70 percent have problems moving closer to the market — such as problems with finding such vehicles for support as venture capital.

Only some of the approaches to tackling the problems lie within the realm of the program itself. Others — the lack of patient, risk capital, and the lack of an innovation culture in the private sector — are outside its scope. It is also a fact that when so few sectors of the Chilean productive sector invest in research, coupled with the importance of SMEs in the evolution of the economy, other measures may be more appropriate "leading edge" indicators of the program's impact. For instance, new collaborations between SMEs, universities and technical institutes, and the movement of people among sectors could be relevant here.

Four specific issues were highlighted as priorities if CONICYT is to increase the effectiveness of the program.

1. Means of increasing the participation of companies, especially where the sector is not well developed in Chile (such as in manufacturing and value-added products). Regional and industrial sector meetings are one such vehicle.
2. Further evolution of the R&D culture in universities, increasing the number of interdisciplinary projects, projects that entail inter-university, university-technical institute and university-company cooperation. Incentives for people to move between industry and university (both directions) would be particularly effective.
3. Means to increase the level and quality of project management, especially of complex projects. This will require an explicit human resources thrust that produces technicians and managers as well as scientists and engineers.
4. Streamlining the program administration.

Many countries have introduced funding schemes along the lines of the FONDEF program, in order to selectively promote some areas of national interest, increase collaboration between higher education and industry, and to support the objective of applying R&D to wealth creation and an improved quality of life. These programs are a vital complement to the longer-range research activity supported by FONDECYT-like mechanisms. But these programs can find themselves "pushing on the end of a string" without a larger and vibrant innovation policy context in which they function.

In some countries, the evolution and functioning of these types of programs are framed by a broad public consultation that helps focus the program activities and inform the evolution of the overarching S&T and innovation policy. The UK, for example, has the widely known Foresight Program designed to secure competitive advantage and enhanced quality of life through:

- creating enduring networks linking business, the science base and government;
- developing a forward-thinking culture about market and technology opportunities and threats; and

- establishing visions of the future, and identifying the developments in S&T that will help the country meet its future needs and acting on the priorities identified.

The Foresight Program is spearheaded by sixteen thematic panels representing important sectors of the UK economy, including such "softer" areas as leisure and learning, as well as retail and distribution). Since 1995, a large number of programs (such as LINK — directed at supporting collaborative research between the UK industry and the science base) have funded research that is responsive to the priorities identified under the Foresight initiative. More recently, the planning and performance of government R&D are being linked directly with the Foresight Program.

The process of "Technology Foresight" has been extensively used in countries such as Japan, Germany and the United Kingdom and is currently in use in South Africa. The Association of Pacific Economies (APEC), of which Chile is a member, has established a Foresight Centre in Bangkok to provide methodological support in Foresight exercises and to promote inter-country comparative Foresight analyses.

Review term of reference 3B

Performance efficiency and effectiveness: assurance of quality, relevance and sustainability

Project support through FONDEF is managed through open competitions for funds based on responses to program announcements that identify the target fields of activity for which funds will be awarded. It ran competitions in 1992, 1993, 1996, and 1997. The current schedule of a competition is explained in Table 13.

Table 13. Timeframe for FONDEF grant approval process.

Activity	Elapsed time
From program announcement to receipt of applications	2 months
From receipt of application to official notification of decision; and operation of the academic evaluation process	6 months
From official notification to release of funds	2 months
Overall process from receipt of application to release of funds	8 months

Two aspects of the schedule merit comment:

1. The time between the announcement and receipt of an application is short. While this can be seen as efficient, it can also preclude applications that demonstrate a deep commitment of both the university and institute and the private sector. Some institutions advocated more lead time to promote quality applications. This outcome could also be achieved by a regular annual competition for which major thematic changes are announced well in advance.
2. The requirement to obtain authorization for each contract from the Controlaría de la Republica following "approval in principle" by FONDEF introduces a

significant time lag into the process. It also appears to run counter to international moves to increased before-the-fact delegation, with stronger regimes of after-the-fact accountability. CONICYT should explore the opportunity of receiving special dispensation from this requirement, based on the program's track record to date.

The program is managed on an operational cost of about 5 percent of the total resources administered, including stipends for the work of the academic evaluation system, and charge-backs for access to CONICYT's support staff. This overhead cost is representative of fairly efficient funding operations in other countries. It is notable that the community found the FONDEF staff responsive to their inquiries and of considerable help in the preparation of applications.

While many attributes of the FONDEF program operation were considered admirable, there was a widespread view that the reporting requirements for FONDEF are unreasonable, and provoke a compliance on paper which is unrelated to substantive R&D outcomes or to any active partnership with industry. There was almost unanimous concern with the frequency and detail of reporting requirements.

We were advised that the reporting requirements have been relaxed from every 3 to 4 months. Furthermore the capacity for electronic submission (the open window) is being implemented.

We are not convinced that these actions will respond to many of the concerns related to the amount of non-productive work invested in reports. We remain unconvinced that the administrative benefits from these reports are a positive attribute of the program. Two reasons lie behind our unease. Firstly, the return on the administrative burden is very small (only two of 50 projects were identified as problematic from the content of their reports). Secondly, reliance on reports induces a culture of dependency and risk-aversion that is antithetical to good research.

FONDEF staff reported that of 50 projects, only 5–7 experienced difficulties. In these 5–7 cases, there was a need to intervene via such interventions as field visits. However, only two of these cases were identified through analysis of the reports (4 percent hit rate). Others were identified as a result of calls from the industrial partner or contacts from the institutions/universities themselves.

We believe that a combination of on-line financial reporting and on-site meetings with all partners would provide a more effective and efficient means of monitoring projects and promoting the program objectives. It also supports the suggestion that the institution being financed could take a larger role in project management.

Two other characteristics of the FONDEF program were identified by those interviewed as adversely affecting the research environment. The first relates to the fact

that an individual may lead a FONDECYT or a FONDEF project, but not both. The second relates to support of research training through FONDEF-funded projects.

As indicated earlier in this chapter, there was concern with the regulation precluding one individual from jointly holding FONDECYT and FONDEF projects as Principal Investigator. This regulation is viewed as inducing creative ways to procure grants, rather than effectively supporting the symbiosis of discovery and application that could flow naturally from active FONDECYT and FONDEF projects proceeding in parallel. In the absence of a regulatory change, long-range basic research is being incorporated within the relatively flexible confines of FONDEF projects or restructuring of FONDECYT teams. Such methods are being used to maintain the dual-research track. This is contrasted with the flexibility in administration exercised by FONDEF program management to permit evolution and change of the project objectives according to its progress.

The issue regarding student support from FONDEF project requires validation. We were advised that as student stipends were unavailable under FONDEF, any students associated with FONDEF projects had to be paid as salaried employees (for instance, as an engineer), complete with allocations for severance pay and other benefits. If this is so, it would seem to defeat one of the most important attributes of a FONDEF project — the promotion of the training of students in research environments oriented to the needs of the private sector. We would advocate even more priority to the issue of human resource development than is the case at present.

There appears to be widespread and genuine confusion with the FONDEF policies on intellectual property, including ownership; the extent to which funding is available for patent costs; and the eligibility of costs for Chilean versus international patents. We were advised that FONDEF funds "some" aspects of the patent process, but expects to see a commitment by the university or institution and the company. Over time, the funding-flow from revenues is expected to support the patent operation at a university or institution On this issue, however, we received such a diversity of contradictory interpretations that the existence of a communication problem was clear.

There were frequent comments that FONDEF provided a unique source of funds for large research equipment through a competitive program. This funding source was considered to be very important by the research community. While we believe that the provision of equipment is an essential component of FONDEF, placing responsibility for all major equipment within this project increases the risk of compromising — or at the very least confusing — the program objectives with the core funding of long-range research. A high priority must be the establishment of a mechanism within FONDECYT for adequate support of equipment needs.

Review term of reference 3C

Evolutionary capacity: ability to respond to changing needs, opportunities and research paradigms

The future evolution of FONDEF will be conditioned by the evolution of an innovation culture within the private sector and the portfolio of program instruments around it, as much as its own design. Situated within CONICYT, FONDEF has a key role in linking discovery with synthesis and application. As the most long-range element of the PIT portfolio, it reinforces the importance of the science base in the national and regional systems of innovation. Its capacity to evolve will mirror the policy capacity of its governing bodies (FONDEF and CONICYT, and to some extent PIT) to continue to situate the program at a dynamic interface of research performers and users in Chile. The evolution of a Foresight Program-like tool would be one means of creating an environment of continuous evolution within FONDEF.

FONDEF was designed as a response to changing research paradigms — in recognition of the increasing importance of constructive interactions among R&D performers, and between research performers and users. The expectation of a tangible commitment from the research user is a key element of its design. We explored the prospects of increasing the contribution of the user sector with mixed reactions. Many felt that it was simply not feasible to increase the 20 percent commitment at this time, particularly with the focus on SMEs. Over time, however, FONDEF should explore whether its program design should be customized to reflect the differing needs of SMEs and large industry. Many countries expect contributions of up to 50 percent for projects undertaken jointly with the private sector.

As indicated above, a critical element in FONDEF's evolution will be a major streamlining of its administrative procedures.

We observed that in comparable programs in other countries there is more dominance of a human resource dimension. These possess one or more of the following components:

- instruments to promote the mobility of researchers between universities, institutes and industry, such as short-term leaves from three months to two years;
- graduate student stipends for co-operative graduate programs in which industry is actively involved in the supervision of graduate students;
- explicit incentives for collaborative projects that involve a high level of graduate student training;
- mechanisms to increase the receptor capacity of SME's for accessing and adopting technology; or
- incentives for individuals to take business ideas beyond the research bench, such as through equity funding.

While it might take some time before such instruments would be extensively used, incentives like these can make a significant difference over time. Their early inclusion in a portfolio of program mechanisms would be symbolic.

There is a growing body of evidence that universities and technical institutes can have direct local and regional economic impact that goes well beyond the direct economic impact of their expenditures. FONDEF has a special opportunity to support the national policy of decentralization through examining means of fostering the mutuality of interest between universities, technical institutes and the local economies of Chile's diverse regions.

While FONDEF has done a good job of catalyzing interest in the synthesis and application of knowledge for wealth generation, it has not devoted the same attention to the "quality of life" and "public good" dimensions of R&D applications. The recent inclusion of health and higher education offer some scope for evolution, but generally this is an aspect of the program that requires development. We note that foregone costs (such as in the health-care system) are as significant an economic windfall to the government and population as are commercialized innovations.

Review term of reference 3D

Funding sufficiency: adequacy of the resource base

We learned that about 1/3 of all FONDEF applications are approved; roughly 1/3 rejected, and approximately 1/3 fall above the threshold for funding, but are not high enough to make the funding cut. Some of those interviewed speculated that university research capacity is currently saturated, with all senior researchers who can do FONDEF type work being fully occupied. However, program management felt that a migration from 33 percent to 50 percent success rate could be fully justified, given the present quality of proposals. Should the active research community expand, or a larger number of more modest projects be supported, the program would be under further pressure.

We noted, as in the case of FONDECYT, that a significant proportion of the funding is devoted to individual salary supplements.

There is reason for the funding of both FONDEF and FONDECYT (including FONDAP) programs to be considered together within the annual governmental budget process and in the larger context of an S&T/innovation policy framework. Together these programs represent the mainstay of support for the "science system" within the NSI. In addition to the FONDEF funding, we believe that attention should be paid to the adequacy of the research base from which ideas and personnel for future FONDEF projects should be drawn — FONDECYT. This should include appropriate provision for equipment support.

CONICYT and its responsibility for policy development

Since its creation in 1968, CONICYT has had responsibility, either explicit or implicit, for defining policy at two different levels. It has had a responsibility in law for the provision of broad advice to the President of the Republic on matters of S&T policy. It has also had the operational responsibility to manage its resources well, which implies a responsibility for developing internal policies to guide its own activities.

Its national responsibilities were first defined in Ley N° 16.74 of February 1968, which required it to advise the President on "the planning, promotion, and development of research in the field of the pure and applied sciences" [translation] (Ministerio de Educación 1971, Articulo 6). Then Minister of Education modified this mandate in Decreto Supremo N° 491 of February 1971 by requiring CONICYT not only to advise the President on planning for S&T, but also "develop, promote, and stimulate science and technology in Chile, and preferably orient them towards the economic and social development of the country." [translation] (Ministerio de Educación 1971, Artic[illegible]6)

The capacity of CONICYT to deliver advice was essentially removed by Decreto Ley N° 116 of the Military Government in December 1973 which dissolved CONICYT's Council. The capacity was restored by Decree 347 of the Minister of Education in July 1994, which restored to the CONICYT structure an Advisory Council whose principal function was to "to support the National Commission for Scientific and Technological Research in the formulation of national policies in its fields of competence through publication of reports and technical studies which could serve as the basis for the same." [translation] (Ministerio de Educación 1971, Articulo 2) In July 1995, this Council published a study entitled "Proposiciones para el Desarrollo Científico-Tecnológico de Chile."

Since its publication, the Advisory Council ceased functioning, in part, we were told, because its large size (of about 40 members) made it difficult to operate.

In Chapter IV we indicated our belief that the Government of Chile needs to define a mechanism to deal with science, technology and innovation policy at an overall level. Once a decision on that mechanism is taken, any ambiguity in the role of CONICYT with respect to advising on broad policy issues should be removed.

No matter what happens with respect to CONICYT's role in national policy advice, we believe that steps should now be taken to improve its capacity to deal with operational policy issues in ways which take into account the needs of the constituency it serves, as well as the changing global patterns of research organization and financing.

At present, FONDECYT's and CONICYT's direct support of basic science and to technology via investigator-driven research primarily in the universities, are subject to the terms set out by the Military Government in Decreto can Fuerza de Ley N° 33/81 and in Decreto 836/82. This pair of decrees set out a governance structure for FONDECYT

consisting of three bodies — a ministerial-level Consejo Nacional de Desarrollo Científico y Tecnológico, and two autonomous, self-appointing Consejos Superiores — one for science and one for technological development.

The Consejo Nacional de Desarrollo Científico y Tecnológico, consists of the Ministers of Education, Finance and National Planning. Its principal function (Ministerio de Educación 1971, Decreto 33/81, Articulo 2) is to decide on the relative allocation of funds to basic science and to technology within the annual budget of FONDECYT. According to information provided to the mission, this Council has met only twice in the seventeen years of its existence and its main function is now exercised within FONDECYT itself.

The main functions of the Consejo Superior de la Ciencia and of the Consejo Superior de Desarrollo Tecnológico are to allocate to research the respective budgets assigned to them (Ministerio de Educación 1971, Decreto 33/81, Articulo 5° and 7°). We were informed that 1998 was the first year in which the Consejos had allocated, *ex ante*, budgets for individual disciplines and hence for the split between support of basic science and of technical development within FONDECYT. We believe that this is an important function for the Consejos to perform.

However, no overall policy formulation roles are assigned to these two bodies. Some members of the Consejos have expressed reluctance to see such responsibility allocated to them.

In a similar fashion, FONDEF operates under Decreto 237/91 of the Ministerio de Economía, Fomento y Reconstrucción. It is managed by a Comité Directivo whose functions are operational — the Comité gives general direction to FONDEF and is responsible for the adjudication and selection of projects (Memoria FONDEF, 1991-1995, p. 7).

Given this understanding of how CONICYT, FONDECYT and FONDEF currently function, we concluded that at present there is not an adequate internal provision for overall policy thinking with respect to the operational role confided to CONICYT by its legislation.

We believe that the time is ripe for a new Board or Management Council to be appointed to oversee the activities of CONICYT and to play an active role in the development of policies regarding the use of funds to be allocated to CONICYT in future. In line with well-established practice around the world, such a council should be of manageable size (say fifteen members); have its membership drawn from the public, private and academic sectors, with members serving on the council in a personal capacity; and ensure that the President of CONICYT is a member of the Council. The President of CONICYT could chair this council, as is the practice in many similar bodies around the world. The Council should also contain at least one member with

functions relating to the operation of the CORFO funds, to ensure clear articulation among the complementary roles being played by CONICYT and CORFO in the support of technological development.

Prior to its submission to government, the Council should be responsible for approving an annual program of work and budget for CONICYT. It should pay particular attention to proposed relative levels of resource allocation to activities such as human resource development, the strengthening of research capacity in the country, as well as to the financing of research projects or programs per se.

In addition, the Council should be the principal forum for the discussion of new program initiatives such as the introduction of the FONDAP program. The Council would exercise a responsibility for ensuring that CONICYT was capable of responding to the kinds of issues discussed in this report.

Under such a system, the Consejos Superiores would continue to exercise their functions relating to grant allocations within the CONICYT system.

The above suggestions have implications for the internal structure and staffing of CONICYT, in that a small policy function would be necessary, to assist the President and the new Council. How such a function should be organized would be for the President of CONICYT to decide.

VI. Other financing bodies

Funds coordinated by PIT

In the early 1990s, Chile's economy grew rapidly, based largely on natural resource factors of production. However, the Chilean government recognized that this growth pattern was unsustainable and that improvements in the way factors of production are used needed to be introduced. Symptoms of potential future stagnation were the relatively high unemployment rate and an increasingly negative technology balance of trade. This situation lay behind the granting of a US $90 million Inter-American Development Bank (IDB) loan to promote programs funding innovation, such as the FONDEF and FONTEC funds.

To stimulate a transition to the next phase of economic development, namely innovation-led development, five priority areas were identified by the Programa Innovación Tecnológica (PIT), a program under the Ministry of the Economy. These were:

1. promotion of technological innovation;
2. modernization of SMEs;
3. development of clean production methods;
4. development of a national infrastructure and communication policy; and
5. promotion of competitiveness in a global environment regulated by the WTO.

In support of these five priority areas, PIT further identified six related issues:

1. the need to modernize the Technological Institutes;
2. the lack of appropriate human resources in key areas of the economy;
3. the need to increase the effectiveness of funding instruments;
4. the lack of innovation management skills;
5. the need for alternative financial instruments such as risk capital; and
6. the need for an effective system for protecting and a culture of valuing intellectual property.

These last six issues, as well as the five priority areas, provide the criteria for the structure and disbursement policies of six funds coordinated by the Executive Secretariat that is located in PIT and advised by an external technical committee. The six funds are summarized in Table 14.

Table 14. Government contributions to PIT funds in 1997.

Fund name	Funding amount (Chilean pesos)
Fondo Nacional de Desarrollo Tecnológico y Productivo (FONTEC)	6 191,4 million
Fondo de Fomento al Desarrollo Científico y Tecnológico (FONDEF)	7 524,7 million
Fondo de Desarrollo e Innovación (FDI)	6 154,2 million
Fundación para la Innovación Agraria (FIA)	2 399,9 million
Fondo de Investigaciones Mineras (FIM)	—
Fondo de Investigación Pesquera (FIP)	2 110,0 million

Although only FONTEC, FDI and FIP receive their budgets from the Ministry of the Economy, PIT plays a coordinating role for the portfolio at the level of innovation policy and also supervises periodic evaluations of the funds. The FIM is funded entirely by the private sector, whereas FONDEF and FIA are on the budgets of the Ministries of Education and Agriculture respectively.

Note: FONDEF has been described and commented on extensively elsewhere in this report. In this section, therefore, we shall concentrate on the other five funds.

Fondo Nacional de Desarrollo Tecnológico y Productivo (FONTEC)

FONTEC finances projects in technological innovation, technology transfer, and technological capacity building and infrastructure. The fund is wholly directed towards private companies that provide either goods or services, from any sector. In practice, the largest number of grants is awarded in the area of manufacturing, with agriculture the next most favoured sector. The state will provide up to a maximum of 50 percent funding for any project, although the firm or consortium needs to obtain security for the liability, should the project fail to meet mutually agreed targets.

An important activity of FONTEC is the funding of technology mission-projects. These are visits by groups of Chilean businesspeople to international partners to promote learning- and information-exchange about technology. Nevertheless, approximately 70 percent of FONTEC funds are spent on innovation and 30 percent on dissemination.

FONTEC does not have an annual competition. Approval time for projects is relatively short, at 40–45 days. This is the time it takes for the financial and legal analysis of the company, and the technical analysis of the project. The time taken from approval to delivery of funds is dependent on the ability of company to provide the security for the liability and averages about 15–20 days.

In general, grant recipients are satisfied with FONTEC's administration and regard it as less bureaucratic than the other funds. However, there is some criticism regarding FONTEC's understanding of new areas, particularly in the fields of information technology. Although it is possible, in theory, for projects originating in FONDEF to be funded at later stages of development by FONTEC, the communication between the two funds at a practical level (as opposed to a policy level) is not well developed. Inhibiting factors are the WTO's restrictions on subsidies for product development, particularly those affecting exports.

A challenge for FONTEC would be to stimulate more innovation in areas that will clearly be strategic in the 21st Century, particularly in the wide application of information technology and biotechnology throughout the economy. As the primary government supply-side instrument for innovation in the Chilean business sector, FONTEC has the responsibility not just to respond to project proposals. It must also develop a culture of innovation in areas that PIT's foresighting activities have identified as being critical for knowledge-based economic growth in the future.

Fondo de Desarrollo e Innovación (FDI)

FDI was created in 1995 and was initially called Fondo para Programas y Projectos de Investigación de Servicio e Interés Publico (FONSIP). It provided a competitive mechanism for disbursing funds to the five CORFO institutes CIREN, IFOP, INFOR, INTEC and INN (see Chapter VII, below). Previously these institutes received baseline funding determined by a formula.

The reduction in baseline funding to the CORFO institutes has taken place fairly suddenly over a period of three years, with only CIREN now receiving any direct subsidy. In 1996, it was decided to widen the eligibility for FDI funding to include other government institutions, the private sector, and the universities. Accordingly, the size of the fund was increased from about US $8 to about US $15 million.

The sector focus of the fund has not changed, with the major portion of the investment still in forestry, fishing and aquaculture, and agriculture. Despite a program

shift toward innovation, even in 1997 a mere 3 out of 35 approved projects had industrial themes.

Any analysis of FDI must be done in conjunction with an analysis of the effect of the removal of baseline funding on the CORFO institutes. The reasons for the complete shift to competitive project based funding were:

1. to widen the access to government funding for innovative projects from all sources and not merely from a few "privileged" institutes; and
2. to ensure that government knows exactly what it is getting for its investment in innovation.

While the two points are based on powerful principles, a danger of this fairly radical approach could be the undermining of Chile's potential to perform strategic research. Now the CORFO institutes are bound to focus more on short-term, bottom-line projects. The challenge for FDI will be to identify key strategic themes effectively and to channel funding accordingly. There is evidence that the FDI management has recognized this imperative (for instance, the salmon disease issue). However, this role of centralized intelligence-gathering — as opposed to leaving it up to the CORFO institutes themselves to decide on the importance of various lines of research — places a huge responsibility on the FDI. It is too early to tell whether the new policy has been successful.

Fundación para la Innovación Agraria (FIA)

FIA was founded in 1981 by the Ministry of Agriculture to initiate and coordinate R&D and to promote the uptake of new technologies in the agricultural sector. Although FIA specifies four areas of focus — agriculture, forestry, animal husbandry, and aquaculture — in practice only agriculture and animal husbandry have had significant emphasis over the past three years.

The FIA management claims it is currently grappling with the problem of identifying real and potential innovations as opposed to more or less competent and publishable research. They also believe that their relationship with the private sector is underdeveloped. There is an intimate connection between these two issues, and they can only be explored together in a fund such as FIA. While no formula exists for identifying potential innovation, giving priority to projects with strong financially contributing private-sector consortium members increases the chance that innovation will occur.

Fondo de Investigaciones Mineras (FIM)

Although PIT plays a coordinating role with respect to FIM, all grant funds derive from the mining industry rather than from government. FIM is a small fund and was established in 1996 under the administration of CIMM. Its purpose is to examine

strategic and public-good issues relating to copper mining. It is distinct from the contract research budgets of CIMM and CODELCO, for example, in that there is a call for proposals. The main interest of the mining industry in FIM appears to be in terms of its potential contribution to an understanding of public-health issues. Nevertheless, FIM is by far the smallest of the funds, with FONDEF, FONTEC and FDI each granting more to mining than FIM does.

The PIT-coordinated funds face three main challenges:

1. To facilitate the level of strategic research normally conducted by State-funded institutions (such as CSIRO in Australia, MINTEK and CSIR in South Africa) following the decision to shift all funding away from technological institutes toward competitive project-based funding.
2. To coordinate, or even amalgamate, the various funds in a creative way that is not excessively rule-bound, given that only a limited degree of content differentiation appears to exist, particularly between FONDEF, FONTEC and FDI. Even for these general funds, the main focus is on agriculture, forestry and fisheries, generating a possibility for overlap with FIA and FIP.
3. To support innovation which is consistent with plans for and which assists current patterns of economic growth. As Table 15 demonstrates, this will perhaps be the most onerous challenge to meet. Clearly the strengths in Chilean applied research currently lie in agriculture, forestry and fisheries. It is in these areas that the majority of innovative proposals originate. However, the Chilean economy is growing much faster in the industrial, commercial, infrastructure and service sectors today. Therefore, researchers should be actively encouraged to align their proposals to these sectors. A better focus of effort will bring benefits not only to the economy but also to the researchers themselves, because these new areas are clearly where local and international private-sector investment will be channelled.

Fondo de Investigación Pesquera (FIP)

FIP was established in 1991 as a sector-specific government fund for research aimed at applications in the fishing and aquaculture industries. It plays a complementary role to FIA in terms of emphasis, with all funds going into either fisheries and aquaculture research, else research into resource management, conservation or relevant environmental issues. Universities, CORFO and other government institutes as well as the private sector are eligible for funding.

Table 15. PIT funds versus various sectoral economic indicators.

Sector	% FONDEF funding (annual average over 1992–1997)	% FONTEC funding (annual average over 1995–1997)	% FDI funding (annual average over 1995–1997)	% FIA funding (annual average over 1995–1997)	% FIP funding (annual average over 1995–1997)	% FIM funding (annual average over 1996–1997)	Approximate % of total summed over all funds	% of GDP generated in sector (1996)	% Contribution towards growth in GDP	% of exports (1996)	% of workforce employed in sector
Industry	8.1	41.2	5.7				16	16.2	8.3	42.3	15.5
Commerce and catering							0	17.8	26.9		18.5
Financial services							0	12.6	12.8		7.0
Mining	18.7	4.8	3.1			100	10	8.3	14.4	46.1	1.6
Transport and communications	8.5[1]	9.7					6	8.2	11.9		7.9
Agriculture, livestock and forestry	38.6	28.5[2]	51.4	95.9			40	6.5	1.4	10.7	13.6[7]
Fishing	15.5	7.5	19.8	4.1	100		16	1.2	0.7	0.2	—[7]
Construction		2.9					1	5.6	8.2		9.2
Housing							0	3.6	1.7		
Electricity, gas and water	1.5[3]	0.3					1	2.6	0.6		0.6
Personal services	7.1[4]	5.0[5]					4	6.2	3.2		26.0
Public administration							0	2.4	0.5		?
Others	6.8[6]		20.1[6]				6	8.8	9.3	0.7	

Source: Private communication from PIT Sistema de Fondos Tecnológicos.

Notes: Figures include funding from all sources, namely government, private and institutional.

[1] Includes information technology.

[2] Includes biotechnology.

[3] Includes energy.

[4] Includes health.

[5] Figure does not distinguish between types of services.

[6] Includes cross-disciplinary projects.

[7] Percentage of workforce employed in fishing is included in the agriculture, livestock and forestry sector.

Instituto Desarrollo Agropecuario (INDAP)

INDAP is an institute under the Ministry of Agriculture that promotes extension in general- and technology-transfer, particularly in the agricultural sector. INDAP is active in both commercial and small-scale farming support. At over 11 billion pesos (1997), it has a large budget when compared with other technology oriented funds. Diffusion is usually a sorely neglected but immensely important part of the innovation chain, particularly where SMEs are concerned. Chile is fortunate to have at its disposal a centralized organization, which has this issue as its main focus. As a mastery of biotechnology becomes ever more critical in agriculture, INDAP should become an increasingly important mechanism to diffuse up-to-date know-how.

The Cátedras Presidenciales

The recently appointed Presidential Committee on Scientific Matters was authorized in 1997 by a presidential decree to establish a competitive system for scientific awards. The Presidential Awards are designed to give significant support to those researchers who are making Chile internationally known for its contribution to knowledge. The awards consist of annual grants (renewable for up to three years) to individual researchers of up to the relatively large amount of 50 million pesos, of which nearly half may be used as an honorarium for the recipient.

To qualify, applicants need to be active in research, especially in the basic sciences, which are the natural and exact sciences of biology, physics, chemistry, and mathematics. Closely related areas such as biochemistry or astrophysics are included. A further requirement is maintenance of significant scientific productivity, both quantitative and qualitative, which has been recognized by the international scientific community. The awards may go to Chileans who normally reside outside the country, as long as they have links to a local research institution and remain in the country for at least 60 percent of the tenure of the award. After the Committee has made its decisions, the recipients sign contracts with CONICYT, which disburses the grant money.

A total of forty Cátedras were awarded in the first three years of competition. The adjudication process involved high-level committees of international peers. The results from the twelve Cátedras awarded in the first round were apparently so encouraging that all awards were reconfirmed for a third year.

Several issues and principles arise with respect to the Cátedras:

1. The awards are an attempt to raise the level of Chile's science (but not technology) base by concentrating resources in the hands of those who have proven track-records. The emphasis on international benchmarking is consistent with this approach. The Committee has also recognized the unique opportunity

which astronomy presents to the internationalization of Chilean science by making five awards within the astronomy community.

2. However, by stressing the career track records of researchers even more heavily than FONDECYT does, the Cátedras contribute toward the under-resourcing of younger researchers. The inclusion of a need to support one younger researcher, while welcome, is not adequate in view of the magnitude of the problem being faced by Chile with respect to the aging of its scientific community. Consideration could perhaps be given to running a separate competition for really talented Chileans under 35. Canada has such a program that recognizes excellence in research exhibited early in a career.
3. One problematic aspect of this system of rewards is the very high proportion of the grant that may end up as a salary supplement to the recipient. The culture of paying oneself out of one's own grant is not unique to Chile and it may well be inevitable in a country where university salaries are so low that unprotected research money will be used to subsidize salaries — rather than to perform research. However, in the longer term, Chile needs to resolve the question of academic salaries in ways other than through the granting system in support of academic research.
4. The Cátedras do not appear to be well linked to national policy considerations. The intended outcomes of the awards seem to have more to do with national prestige than economic or social development. In many countries a key policy objective for public funding of high quality scientific endeavour is promoting top quality human-resource development. However the Cátedras appear not to be oriented toward developing research competence but rather toward rewarding existing competence.

   The very narrow limitations on eligible fields further constrict the potential of these awards from contributing to Chile's long-term economic or social development.

   Given the important changes in the way in which research is now organized, and which were discussed earlier, the potential of the FUNDAP mechanism seems greater than that of the Cátedras to contribute in the longer term to both the health of basic science, as well as the underpinning of Chilean economic and social development.
5. The results of the three competitions, not surprisingly, have reinforced the domination of institutions located in Santiago within Chile's academic science system.

Table 16. Distribution of Cátedras Presidenciales by institution.

	Pontifica Universidad Católica de Chile	Universidad de Chile	CIMM	Universidad Técnica Frederico Santa María, Valparaíso	Chileans in USA
Round 1	7	4	1	—	—
Round 2	2	9	—	—	3
Round 3	6	5	—	1	2

The distribution of the Cátedras by discipline is shown in Table 17.

Table 17. Distribution of Cátedras Presidenciales, by discipline.

	Round 1	Round 2	Round 3	Total
Life sciences				
Biochemistry	1	—	—	1
Biology	2	4	9	15
Biophysics	1	—	—	1
Nutrition	—	1	—	1
Pharmacology	1	—	—	1
Natural sciences				
Astronomy	2	2	1	5
Chemistry	2	3	1	6
Geology	—	1	—	1
Mathematics	1	1	3	5
Physics	2	1	1	4
Total	**12**	**13**	**15**	**40**

During the period when we were in Chile, it was still not clear if those scientists who had won Cátedras in Round 1 would be permitted to become candidates for a second award. If they are not permitted to resubmit their candidacy, this would make the Cátedras more of a prize than a program of research support, and lead to questions about the nature of the awards and their rules, which seem inappropriate for a prize.

Scholarships

The Ministry of Planning runs a scholarship program for Chileans to study abroad for postgraduate degrees. Since its inception by the Military Government in 1981, the cumulative target number was 1 400. Thus far, 1 149 scholarships have been awarded. Although there may have been some initial logic for the location of this program in Ministerio do Planeación (MINEPLAN), due to the element designed to upgrade the qualifications of public officials, it is hard to see why it does not now fall within the responsibilities of the Ministry of Education. It is particularly important to articulate this type of program, and have its needs identified by CONICYT and CORFO.

Scholarship programs are also run by several universities. In general, any program which facilitates the entry of young scientists into the Chilean NSI needs to be encouraged. However, no scholarship program will have its desired effect if the uptake of young researchers is not facilitated by the implementation of a workable exit program for academics of retirement age.

Funding from the business sector

Traditionally, the private sector has not been strongly involved in funding R&D in Chile. This has been seen as the responsibility of the state, either via the universities or the technological institutes. There are two main reasons for this:

1. the lack of integration of Chilean science into an overall innovation framework that has meaning for the private sector; and
2. the dependence of the economy on the export of unbeneficiated raw materials.

Policy-makers have recognized the dangers inherent in this situation and several of the funds described earlier (such as FONDEF and FONTEC) require a financial contribution from the private sector as a primary condition for project approval. There is evidence that elements of the private sector have begun to realize the potential rewards that research embedded into their business processes can bring. In particular, the mining industry's preparedness to fund CIMM without any state baseline contribution is fairly remarkable.

Nevertheless, although the amount of R&D financed by the private sector has fluctuated around US $60 million during the 1990s according to informed sources, the percentage with respect to the total national spend has dropped from a high of 23 percent in 1992 to 15 percent in 1997. Currently the only government incentive for funding research, apart from partnership in the various funds, is the 50 percent tax deduction permitted for donations to universities. The response to this somewhat unfocused measure has been strong, with donations rising by a factor of 20 since the beginning of the 1990s to a current figure of around US $30 million.

The attitude of decision-makers in the Government of Chile toward fiscal incentives for funding or performing R&D is not positive. Their sense is that unmanageable abuses and distortions will outweigh any benefits. A first step in the direction of developing a system of indirect incentives which the government trusts might be to refine the scheme for rewarding donations to universities by providing some form of tax benefit for donations aimed at supporting R&D.

CONICYT is aware of the current deficiencies in statistical reporting of private-sector spending on R&D, and acknowledge that the data that they publish is likely to represent an under-reporting of its true magnitude. However, even correcting for these statistical limitations, the picture which emerges is still one of significant under-investment.

Funding by regional governments

Regional governments play a small but potentially significant role in funding innovation, particularly at the development and diffusion end. We understand that the central government is committed to disbursing a major portion of its operational spending (some 42 percent) through regional structures. Statistics do not appear to be readily available, but it would seem that budgets of between US $1 and US $5 million are the norm.

A significant portion of regional money spent on technology is allocated to PIT institutes and to INIA, which are both well positioned to undertake development work. Nevertheless, regional government budgets present opportunities for regional universities, too. They, however, do not appear to have taken up the challenge of obtaining funds from this source to any extent. Given the fact that regional administrations are appointed from the centre rather than elected within the region, it is understandably more difficult to play a regional card in funding requests than would otherwise be the case. Nevertheless, putting pressure on regional governments may well prove to be a more effective route toward decentralizing research funding than will changing allocation rules for central funds.

Performance within the national system of innovation

VII. Principal science and technology institutions of the national system of innovation

The universities

The universities of Chile are notable in their range and number. There are probably over 60 universities, within which 25 are members of the Council of Rectors. These latter constitute the group that possesses a longer history and that receives a government-funding base. With one exception, our research team's visits were confined to this group. This was logical given that 92 percent of FONDECYT regular award-funds are received through the competitive process by these universities (CONICYT 1998). Even in the group of 25, there is great diversity in size, location and level of funding interaction with FONDECYT. Indeed, the two senior Santiago universities have accounted for some 60 percent of FONDECYT regular funds in 1996–1998. A further group of four in Conception, Valdivia, Santiago and Valparaiso account for 24 percent, while the remaining 19 account for 8 percent. The top institutions enjoy a similar share of FONDEF awards. A significant number of regional universities came into being as campuses of the two senior Santiago universities. They were converted to independent status by the Military Government's university reform program.

It must be noted that the research-funded universities are the principal site of basic research for the country, a site of significant applied research and the overwhelming locales which stimulate interest among young Chileans interested in research. These are important and appropriate roles for such institutions and it should be a concern of public policy to ensure that they have the means available to fulfil the tasks involved.

Funding for universities that are members of the Council of Rectors

The present complex, and in many ways problematical, process for offering public financing to Chile's "traditional" universities dates from the Reform of the Universities undertaken by the Military Government for a variety of reasons, one of them being a desire to make the universities more responsive to the "markets" which they were perceived to serve, whether this was the market for education for young Chileans, the market for research results or the market for more diffuse concepts as "the advancement of knowledge."

An official involved in the budgetary process told us that the universities meet their institutional operating costs through these components of public funding:

- Aporte Fiscal Directo is a historically-based grant which is not directly related to current costs;
- Aporte Fiscal Indirecto is small award related to enrollment of students obtaining the highest marks in the annual national entry examinations for university study; and
- Fondo de Desarrollo Institucional is given for institutional development support.

The above three components all pass through the budget of the Ministry of Education and may account for some 25–33 percent of institutional operating revenue, according to latest estimates. In addition, the other principal sources are:

- Student fees cover 50–60 percent of university costs. This figure is very high. The average for OECD countries is 38 percent, but some industrialized countries have much lower figures. The contribution of student fees to university budgets, for instance, is only 9 percent in Canada and 2 percent in the Netherlands. To complicate matters, we were told that the Chilean government provides student loans to make university education "affordable", but that the delinquency rate with respect to repayment is high, so that the loan programs are inefficient indirect subsidies to university education.
- Competitive research awards from CONICYT or other government funds are allotted in amounts that are highly variable across institutions.
- Research grants or contracts from the private sector may be large, but may not pass through the university administration. Consequently, they only benefit the research group involved and not the institution as a whole.
- Institutional revenue generation is also highly variable across institutions. For example, in Antifagasto, we heard that university property was being sold for housing development in order to supplement the institution's income. Elsewhere, we heard of the high reputation of the brandy produced and sold in the market place by one university faculty of agriculture!

The outcomes from the current pattern of funding of the universities as institutions and of research within those institutions, create an academic research culture in which possesses six main features.

1. The universities provided minimal research infrastructure due to low funding levels. Nonetheless, a few universities were valiantly attempting to remedy this by designating some of their scarce funds for physical infrastructure, as well as for more deliberate research management, support and business linkage.

2. There is extensive reliance on part-time instructors for teaching. These appointments may account for as much as 50 percent of total academic appointees. There is no expectation of research activity by the part-time appointees.
3. Salary levels of full-time academics are low and it has been traditional practice to earn additional income. It must be noted that this has probably contributed to building some strong connections between academics and both industry and government, which are not necessarily related to research. However, there would be little incentive for academics to use time to do research at the expense of generating additional income.

   We noted that this was the basis of the decision to permit FONDECYT's funds to supplement researcher salaries. This now accounts for 25–30 percent of FONDECYT awards and apparently can improve the remuneration of an early-career applicant by up to 50 percent.
4. Retirement pensions for academics are very unappealing and discourage retirement of faculty members. This works against renewal of research talent and can result in additional pressure toward research inactivity. We heard widespread concern expressed about the aging of university researchers.
5. Some 40–60 percent of full-time faculty would have a research degree — and this was taken by some universities to be an indication of being research active. In actual fact, numbers of FONDECYT/FONDEF awards, numbers of academic researchers recognized by the Chilean Academy of Science, and numbers of researchers indicated by the President's Advisory Committee were much less. We believe that research-active academics probably constitute a minority of faculty members, even in the two major universities in Santiago and a much smaller minority in others. While this may not, however, be true in individual departments, in aggregate it represents a problem for university education in the country.
6. There is a low level of Ph.D. study in Chile with only some 60 students completing per year. The expected additional investment by Chile and the World Bank, through the Ministry of Education's MECESUP program (discussed in Chapter VIII) will help with graduate-student support and numbers. But more must be done to utilize the skill of research-trained graduates in knowledge-based business.

On a more constructive note, we have found that some universities are starting to have offices designed to assist researchers in their dealings with clients. These offices provide advice on matters such as intellectual property, and in some cases provide direct assistance to researchers so they can formulate larger research proposals to funds such as FONDEF. These initiatives are indicators of growing institutional interest in research as

an activity which no longer can be viewed only as an autonomous act undertaken by individual academics.

The above factors, coupled with relatively low direct-research funding (0.7 percent of GDP), and few employment opportunities for research-trained graduates, seriously work against maintenance of a vibrant research culture in the universities. We see this as a very serious impediment to success in innovation.

Views of FONDECYT and FONDEF

The team had an opportunity to discuss these programs briefly with senior administration and with faculty members who have had experience with these funds. The views represented below are widely representative. We repeated them here (since they were raised in Chapter V in the evaluation of the two funds) to give a sense of the "client-community" view of the funds.

Comments on FONDECYT

- greatly appreciated although believed to be substantially underfunded;
- anxiety expressed about the small size of the Chilean review community and resultant perceived conflict of interest situations in the FONDECYT adjudication processes;
- annual reports required by FONDECYT believed to be of dubious value, and may be counterproductive as they result in an increasing dependence of the researchers upon reviewers' opinions;
- the award system is seen as being very conservative and unable to operate beyond the disciplinary confines of the current committees;
- it is believed to be extremely difficult for early-career researchers to obtain funding via FONDECYT competitions;
- there is no understanding of why "complementary awards" cannot entail more than one university — this rule works against the breakdown of the current barriers which diminish contact among universities;
- there is no opportunity to obtain major equipment — modern research cannot be sustained without it and this is considered a major gap in FONDECYT support;
- extreme rigidity of operation to the point that commitments to numbers of papers, journals of publication, and meeting presentations in a project proposal, are all treated in what amounts to a contractual fashion in assessing performance;
- inappropriately low level of support of social and cultural research;
- in smaller regional universities, an added challenge is a deeply held suspicion of bias in the system in light of the overwhelming dominance of the Santiago

universities in awards and in positions influencing review and decision-making; and

- it is illogical to have the Ministry of Planning doctoral program operated separately from its CONICYT equivalent.

Comments on FONDEF

- it is difficult to generate interest from the private sector in participating in joint projects which is the key requirement of FONDEF grants[4] (a counterbalance to the often negative views of the lack of utility of university research held by many in the private sector);
- there was expression of difficulty in achieving industrial use of technologies resulting from the projects, which suggests uncommitted industry involvement and, in addition, a likely lack of knowledge of the constraints operating in the market at which the technology development had been aimed;
- the requirement of reports at intervals of four months is extremely costly in time and work, and apparently serves no useful purpose;
- the requirement that all purchases over US $500 must have several quotes is time-consuming and impractical;
- for some considerable time, FONDEF has been almost the only source of support for the development or improvement of research infrastructure. This aspect of the FONDEF program is highly valued. It is unclear, however, if this was deliberately intended, by FONDEF, to be a way of shaping the research capabilities of the universities toward the needs of industry;
- the regional institutions believe a bias toward Santiago exists, but there is evidence of regional infrastructure and research that relates to the economic activity of the area;
- no convincing reason has ever been presented by CONICYT, FONDECYT or FONDEF for disallowing a researcher to hold both FONDECYT and FONDEF awards simultaneously; and
- in spite of this being a program of partnerships with industry, there is little concern with intellectual property protection.

[4] An earlier evaluation of FONDEF in an unpublished 1995 report by Invertec IGT for CONICYT, "Evaluación de los instrumentos financieros de fomento al desarrollo tecnológico de Chile", concluded that there was little evidence of real participation by firms in early FONDEF projects.

Some suggestions

We welcome the proposed review and accreditation of universities that may be undertaken within the MECESUP investment now being launched by the Ministry of Education, with some support from the World Bank. This process should entail a review of research activities, and should result in investment in research infrastructure and salary levels, as well as in student research-support in those locations identified as demonstrating excellence. It is emphasized that excellence needs to be judged in the context of innovation, rather than exclusively disciplinary-cited papers. Thus, creative applied work that may have a limited research community worldwide, but be very important to Chile could, and should, be considered excellent. This would yield an outcome of targeted research infrastructure like that in the United Kingdom. It would be a means of addressing all aspects of research infrastructure, including quality of faculty appointments, start-up support, and research culture.

Development of a strong, popular, post-graduate research system will be evolutionary, requiring the achievement of recognition of domestic graduates and the provision of employment opportunities. In the meantime, a great deal could be achieved for innovation in Chile by creating expanded opportunities for graduate students and new opportunities for undergraduate students to obtain research experience. They would impart vitality to the process and be receptive to the use of new knowledge after leaving university.

There is a widely acknowledged need for Chile to come to terms with the aging of its research system and of its university faculty. The team encountered some institutions that are managing to cope with the aging of staff through early retirement by incentives and use of performance agreements with individual faculty members. This approach could be more widely adopted.

There must be serious investment in and commitment to research management in those universities committed to research. This includes the need for discovery and protection of intellectual property, and for developing high-quality research interactions with industry. Excellence in industry interaction is essential in a system of innovation. Although all the universities participating in FONDEF must have some industrial linkage and institutional capability for creating a proposal, the team saw only a few examples of good practice. It is recommended that research administrative units share "best practices."

Technological institutes

We visited six institutes, three of which were CORFO organizations — INTEC, INFOR, and IFOP. The other institutes included in our sample were the Fundación Chile, INIA, and CIMM.

One of the most important discussions in technology policy now active in Chile concerns the role of the state in the financing and operation of technological institutes.

As a result of a recent (1996) action, the CORFO institutes no longer receive base public funding through an annual budget appropriation. Rather, as outlined in a recent CORFO policy document (CORFO 1998), they are expected to derive income from a variety of general sources:

1. from a performance contract with a relevant ministry for the provision of "public good" contributions, information needed for resource management or regulatory purposes could qualify, for example, and INFOR has a first such contract with the Ministry of Agriculture;
2. research contracts financed by government under its competitive financing system (Los Fondos Concursables de Investigación);
3. research or technology development contracts from private-sector clients; and
4. sale of technical services or of technical information to clients.

It is interesting to note that the CORFO document does not refer to revenues from the utilization of institute-owned intellectual property as a significant potential source of income. INTEC, for example, indicated that it generated only 4 or 5 patents over its 30 year life, but that a significant amount of its output is protected by copyright, creating the possibility of income from licensing.

These organizations are all expected to have a role in achieving technology adaptation and uptake in their sector. But there are very fundamental differences among them. The overall impressions of these institutes, as obtained from our interviews in relation to the performance functions[5] of Chile's innovation system, are presented in Table 18. It indicates the range of activities now being undertaken by this sample of institutions.

[5] As listed in Appendix III.

Table 18. Some of Chile's public technology institutes and the performance functions of the NSI.

Function	INTEC	Fundación Chile	INIA	INFOR	IFOP		CIMM
					Marine fisheries	Aquaculture	
Performance of R&D	Although still a function, R&D is now being replaced by transfer of technology, (particularly in the areas of environmental technologies, IT, quality management and analytical techniques) as the principal focus of attention	An important function; main areas are related to creation of new industries to use Chile's natural resources (aquaculture, food technology, forestry, and forest products)	INIA is the principal performer of research in agriculture and on livestock in Chile	Has a 3-year contract with Ministry of Agriculture to "maintain required capacity for policy analysis, research, technology transfer and provision of statistics on the forest industries"; this contract yields only 20% of INFOR income	Development of fish stock models for regulatory purposes	Claims to be responsible for 40% of all Chilean activity in the field	A declining function due to change of CODELCO strategy; in future CIMM will be more exclusively interested in filling gaps in long-term "public good research (e.g. re health and environment issues)
Creation of joint ventures, networks or consortia for R&D	Seeks strategic alliances both inside and outside Chile	Uses subcontracting with universities as an element of its strategy	Has a long tradition of cooperation with universities, but new competitive funding mechanisms are putting INIA staff into competition with academic researchers	In fact has only limited resources for research which are obtained competitively from FDI, FONTEC, FIA and private sources; uses about 30% of its income to subcontract for work elsewhere — mainly in universities	Appears to work alone in fish stock management; (note: the FONDAP project in this area claims that there is little going on!); works with both industrial and artisanal fisheries in other areas	Does some joint work with Universidad de Chile but needs to learn how to work with non-traditional partners in the food industry	CIMM has always worked closely with universities (more than 2,000 students have passed through the institute)
Provision of technical services including product testing, trouble-shooting, calibration, resource surveys	An important role in each of its areas of activity. Offers training services in addition to other technical ones	Provides services relating to quality certification; also does more general consulting on technical problems; offers training	Important role in protection of natural resources and biodiversity	Has an important role in resource surveys relating to forest, watershed and landscape management	Provides technical input to the work of the Subsecretaria de Pescas; does technology transfer to marine fishing industry	Not clear as to how many services are provided to aquaculture producers	Its affiliate, CIMM Technology and Services S.A., is the principal firm engaged in the the transfer of technology and provision of technical services for mining in Chile and in the Latin American region

Table 18 continued.

Function	INTEC	Fundación Chile	INIA	INFOR	IFOP		CIMM
					Marine fisheries	Aquaculture	
Provision of mechanisms to link R&D outputs to practical use, including brokerage services	INTEC describes one of its strengths as "managing high-impact innovation"	Uses its power to create small enterprises as a diffusion strategy	Uses "traditional methods" of field days, publications; plus has links to producers associations and to INDAP & PROFOS, but Chile lacks a formal agricultural extension service	Has been developing "technology packages" for forest production for transfer to private sector	Has direct linkage to the regulator, the Subsecretaria de Pescas and works to adapt foreign stock management models to meet Chilean conditions		Has traditionally worked specially for CODELCO with which its links are close
Provision of mechanisms to improve access by SMEs to needed technology	Crucial role; INTEC, with CORFO, is exploring the possibility of creating a Chilean "technology extension service" to expand access by SMEs to needed technology; however, to date, sees low demand for technology by SMEs	May franchise successful technology packages to enterprises but does not assume a general responsibility for the technical health of existing SMEs.	Each regional centre has linkages to local producers organizations; attempts being made to reach small producers	Sees increasing need to help SMEs introduce new value-added wood products into relatively undeveloped domestic market	Is involved in development of new fishing grounds for new species which could become important to artisanal fishery enterprises	Deals more easily with larger companies	Not a preoccupation in the present
Provision of linkages to regional interests, programs and activities within the country	INTEC maintains links with regional universities and is launching some pilot studies on university campuses targeted at pre-competitive research	Subcontracts with universities outside of Santiago	Has 8 regional centres and has been required, by Ministry of Agriculture, to allocate a greater decision-making role to the local steering committees	Maintains research capacity in 4 locations within the country	Maintains 17 offices in coastal locations for data acquisition	Research, in geographical terms, is concentrated in Region X	Closely linked to the interests of the mining regions of Chile

(continued)

Table 18 concluded.

Function	INTEC	Fundación Chile	INIA	INFOR	IFOP		CIMM
					Marine fisheries	Aquaculture	
Provision of linkages to international S&T activities	Seeks international strategic alliances in pursuit of its objectives.	Seeks relationships for the importation of specific technologies	Has contacts via the International Centers of the Consultative Group on International Agricultural Research (CGIAR)	Has a working link with New Zealand in introduction of new approaches to work with SMEs (equivalent to "farming systems" approach used in agriculture	Has good international links and is subject to regular external evaluation	None mentioned	CIMM is well connected internationally and has a good knowledge of what other mining institutes are doing; it has branches in Ecuador and Peru
Provision of mechanisms for evaluating, acquiring, and diffusing best-practice technologies	Operates a "technological antenna function" to seek to identify demand and supply for technologies	One of the fundamental strategies employed by the Fundación	May do so via the CGIAR link	None mentioned	Has links to foreign organizations involved in modeling fish stocks	Not indicated as a function	Not discussed
Creation of innovative goods, processes and services embodying the results of S&T activities and their introduction into appropriate markets	One of the goals being pursued; INTEC is also, with partners, experimenting with an incubator as a means of commercializing new technological ideas	The Fundación commercializes its technology by creating small enterprises and launching them into the market — a unique strategy in Chile	Main task is development of practical production technologies for Chilean Agriculture; acknowledges some successes and some difficulties in transfer process	One part of the mandate of INFOR, but it also has other roles relating to resource management.	Not relevant	Is developing new technologies but still working on relations with private sector to improve commercial use of them	CIMM participates in a wide range of R&D projects and programs with mining companies; however, some of this role is increasingly being taken over by CODELCO's own in-house R&D program
Creation of joint ventures, networks or consortia for the exploitation of intellectual property	Not possible because of limitations of INTEC mandate	A recent emphasis; potential partners are mainly foreign	Not a role for INIA; there are other organizations in Chilean agriculture with a mandate for this kind of activity	INFOR sees itself as a competitor rather than a potential partner of Fundación Chile	Not relevant to regulatory role played by IFOP	Still trying to understand how to relate to companies in the food industry	CIMM has created technology-based firms with private partners

Although most of the institutes conduct some research, their attention is really and properly focused on problems of development and adaptation as contrasted with FONDECYT's emphasis on basic discovery. There was only a little evidence of connection between the institutes and universities. It was disturbing to find that INIA, for example, now sees universities more as competitors for funding than as the partners which they were in the past. This sense of competition must be heightened in a situation in which part of the researchers' salaries are dependent on the winning of research grants.

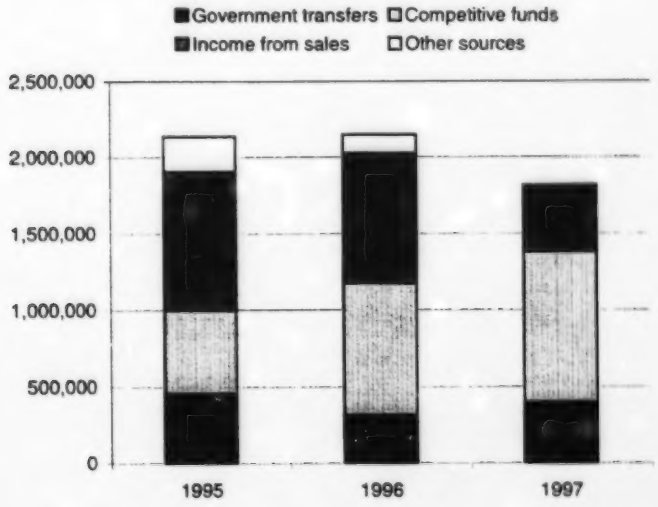
The following five Figures, adapted from the CORFO planning document cited earlier[6], show variations in financing of the five CORFO institutes based on their incomes from these sources:

1. transfers from a ministry budget;
2. financing from competitive funds;
3. income from sale of services; and
4. other sources of income (undefined in the CORFO document).

By 1997, two of the institutes (INN and INFOR) had ceased to receive any transfer from a government ministry, making them entirely dependent on the other three sources of income.

The patterns of financing of all of the institutes in the set show either stability or a tendency to decline. The picture is not encouraging.

Figure 1. INTEC sources of income.



[6] Marco de Política para el Sistema de Institutos CORFO, op cit., pp. 14, 16, 18, 20, 22.

Figure 2. IFOP sources of income.

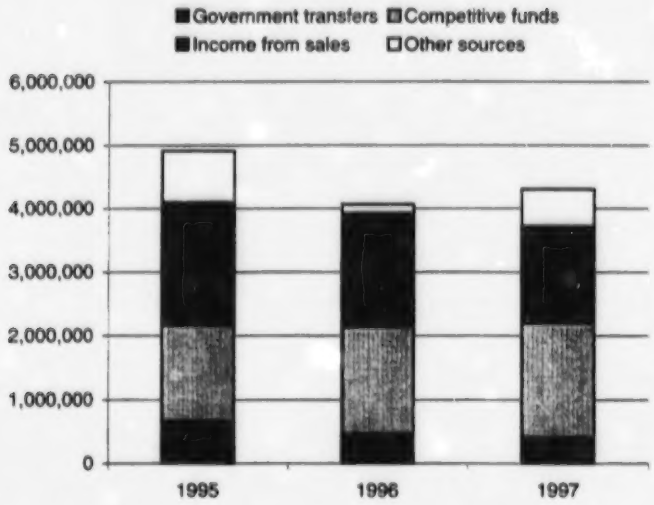


Figure 3. INFOR sources of income.

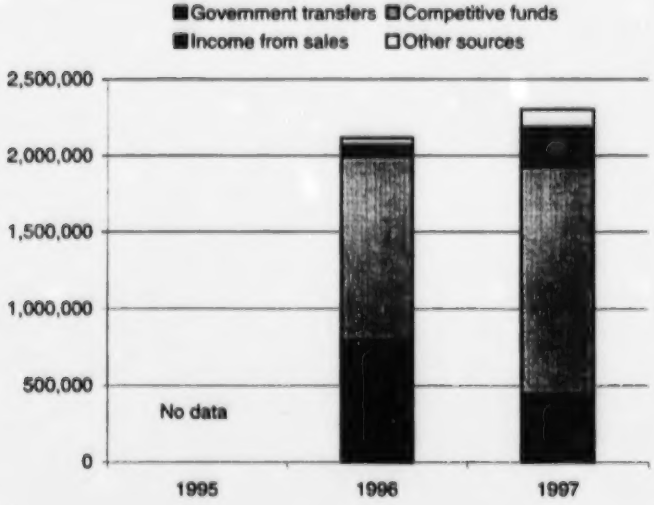


Figure 4. INN sources of income.

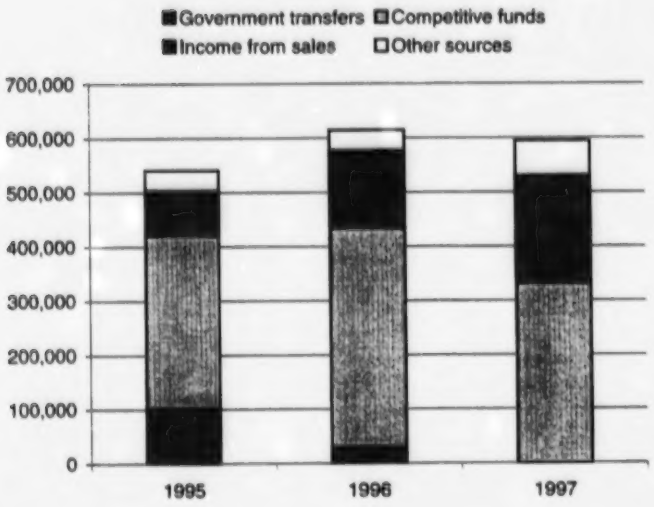
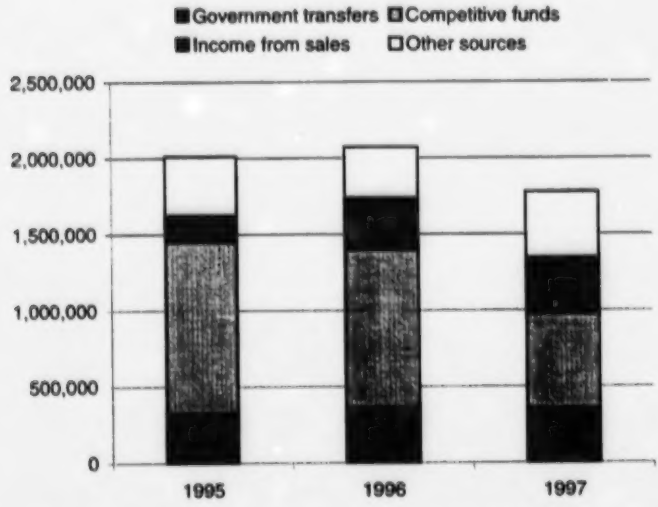


Figure 5. CIREN sources of income.



The current emphasis on competitive funding for the technology institutes is intended to allow them to operate in a manner that is more directed to client and national needs than was previously the case. The manner in which the competitions are operated would then have a very real shaping influence on the institutes; and it would be logical for the intended clients to have a significant role in this. We have only limited information on this point. It would seem, however, that today's level of dependence on

competitive funds by CORFO institutes means that they have pursued funding from financing sources which do not insist on close client linkages at the expense of retaining the sought-after client orientation.

Attempts by government to provide financing to institutes from resources other than the budget of the state is a particular concern at INIA since agricultural research around the world has traditionally depended on such sources. However, in Chile we found no evidence of the practices used in some other countries of financing some or all research on particular commodities via some form of production levy (fondo parafiscal). Latin America's most successful example is probably the financing of research on coffee by the Federación de Cafeteros in Colombia. We did, however, hear that the wine industry in Chile has begun to finance research (related to the health impacts of wine consumption) in a major university. We find this move encouraging. There should be detailed discussions between INIA and the Ministry of Agriculture to determine an acceptable level of base funding for agricultural research in Chile. This is because of both the industry's importance and the need to involve producers more closely in financing activities.

The Fundación Chile represents a unique Chilean experiment. It is a technology centre that improves the technical performance of economically important sectors by creating new companies, rather than by attempting to upgrade the technological performance of existing firms. It launches demonstration companies into the marketplace as a means of commercializing technology that is new to Chile, and later sells those enterprises once they have become viable. According to its representatives, it has launched thirty-six such ventures. Seventeen have been sold, and the most successful six of these have generated more economic activity than the total cost of the Fundación during its existence.

In a recent South America-focused Inter-American Development Bank (IDB) review of technology centres (Mullin 1998), the features of successful centres were discussed. Of note were needs for a clear but broad mandate, an entrepreneurial management style allowing flexibility of interaction with clients, a well-defined role of public financing, regular use of measures of performance, and clear policies for intellectual property. We fully expect that Chile is using similar reference points in its consideration of its institutes. We also note that client responsiveness can be enhanced by strong client inclusion on an institute's Board of Directors, in expectation that such Boards should be closely involved in policy formulation and alert to its implementation. Clearly, this is a step that is underway for the regional units of INIA. As well, it could be a means of bringing greater industry commitment, partnership and funding to INFOR.

We noted that both INFOR and IFOP seemed to have difficulty in simultaneously handling their dual roles of public good and business building. INFOR is frustrated by

the expectation of continual forest resource information and monitoring in the absence of funding. In contrast, IFOP appears more comfortable with fish-stock assessment and monitoring (using regional funding) than with development of aquaculture and its associated value-added steps. Given that the orientation of agriculture is to excel in sustained bioproduction, and that INFOR is being moved into a closer relationship with the agriculture ministry, it may be sensible to have responsibility for aquaculture reside in this area.

One indication of the need to strengthen the linkage between the institutes and much of the research done in universities is provided by the generally negative (but, we believe, uninformed) view held by FONDECYT grant recipients of the quality and focus of the work of the institutes. Criticisms offered to us by academic researchers tended to be sweeping and disparaging — but not accompanied by details. A well-functioning system of innovation would have sufficiently extensive linkages among institutes and academic research centres such that up-to-date information on what each is doing would be readily available.

Regarding linkages, we were also informed that the earth sciences — which is of great importance to Chile — there were a series of public institutions involved in research and/or related technical activities. This includes the Ministry of Mines, a geological survey, the Institute of Geophysics at the Universidad de Chile, the Antarctic Institute, CIMM and CODELCO. But there was little coordination or cooperation among them. In other Latin American countries, serious attempts are now being made to coordinate technology-development activities within broadly defined "production chains" (cadenas productivas). The Acuerdos Sectoriales de Competitividad in Colombia, and the Agendas Industriales, Sociales y Regionales of CONICYT in Venezuela are two examples. Chile might consider experiences such as these as it attempts to create more constructive interactions within its NSI.

Clearly, Chile is experimenting with its operation of technology institutes. We see this as an opportune time to integrate these very important resources, including hundreds of skilled and dedicated people, into a system of innovation. This will require understanding of, and connectedness with, the system.

Firms in the private and public sectors

Since 1973, Chile has followed a hard-line, free-market economic model, where foreigners compete on equal terms with locals, and where it is assumed that free trade will ultimately contribute to the country's wealth. This has meant successive reductions in import barriers and an acceptance of the international norms defined by the WTO. Despite a 70 percent reliance on commodities for its exports, macroeconomic stability is high. Savings are high at 28 percent of GDP, growth has averaged 6.6 percent over the

past 13 years, and inflation is comfortably within single figures. Key service industries such as telecommunications are highly deregulated and tariffs are low.

The Government of Chile has identified the infrastructure deficit as a major bottleneck for continued economic growth and it is estimated that losses in competitiveness of around US $ 1.5 billion a year are currently being generated as a result. Although the infrastructure deficit presents huge opportunities for investors, some government role is necessary to provide subsidies. Surprisingly, the same urgency does not appear to exist with respect to the obvious technology deficit in Chile[7]. Indicators of this are a 1996 National Survey of Executives (Aldunate V. 1998, pp. 23–24), where the question of innovation and technological change was apparently not asked. This is despite the fact that technological change is recognized internationally as being the principal driver of economic progress[8]. Accepting the contribution of technological change to economic growth underlies the attempts of many industrialized countries to develop policy frameworks for the promotion of innovation as a primary route to drive continuous processes of technical change throughout their economies. In the same survey, executives saw fluctuating prices of exports as a threat to the economy. Clearly, it is commodity prices which fluctuate most (copper is a relevant example), with value-added items being much more stable. The 70 percent dependence of Chile's exports on commodities clearly points to another equally serious bottleneck.

Official statistics show that the Chilean private sector currently funds about 18 percent of the country's R&D — but performs a mere 3 percent of these activities. If this figure is accurate, it reveals an astonishing gap in the NSI. One reason why 3 percent might be a serious underestimate is the fact that expenditure on R&D is not recognized explicitly as a tax write-off; it is counted merely as a general cost. There is, therefore, no financial reason for firms to record R&D expenditure. CODELCO, for example, claims to spend US $ 20 million (both in-house and contracted out). But this figure is not recorded on financial statements. Nevertheless, of the indicators presented in the World Competitiveness Report, Chile performs rather poorly in R&D spending and patenting.

In an interview of business leaders that focused on the topic of innovation, the following seven issues emerged:

1. Although there are strong links between business and universities, particularly at the human-resources level (for example, there is a tradition of part-time professorships being held by businessmen), the university mentality is not geared

[7] Although no figures exist for the technology balance of payments in Chile, the capital goods deficit has grown rapidly in recent years.

[8] For example, a declaration issued at the conclusion of the OECD Ministerial meeting, June 1990. The assembled ministers had agreed that technological change was a fundamental source of economic growth in the OECD economies.

to solving problems within a business timescale. This is a frustration. Funding is not nearly as much of a problem as is the orientation of the researchers.

2. Patenting is not well developed in Chile. It is hard to measure the real outputs of R&D.
3. There are real success stories of industry-university collaboration. In the case of REUNA, the Chilean Internet company, several years were gained by the farsightedness and drive of engineers with strong university links.
4. Venture capital is hard to obtain and it is difficult to convince financial institutions of the value of knowledge-based industries. To obtain funding for innovation which is entirely new, rather than simply incremental, is also very difficult. A concerted campaign needs to be run to change this.
5. Generally, the PIT funding system does not take industry's advice as to which areas of research are important. There is a need for the state to support long-term research, rather than simply reacting to the proposals of researchers. The method of Technology Foresight should be investigated.
6. Indirect incentive mechanisms such as tax credits should be urgently investigated.
7. Knowledge-diffusion mechanisms in Chile are completely inadequate, particularly with regard to supporting SMEs. The government places a lot of emphasis on generating knowledge, but none whatsoever on diffusing it.

The private-sector effort is central to any program to embed innovation in the economic life of the country. It is essential, therefore, to develop a good portfolio of measures to stimulate and support innovation in the private sector. Recently, with the introduction of funds such as FONDEF and FONTEC, Chile has begun to support direct incentives. However, a great deal of suspicion still exists with respect to indirect incentives. Although this caution may prove well-founded, there is a growing body of international experience in tax incentives for R&D and innovation which includes much that is positive. We strongly recommend that Chile acquaint itself with this information by means of a formal study.

The mode or extent of technology uptake in the business sector critically depends on the size of company, what its core business is, and on whether it is privately owned. Table 19 indicates Chilean attitudes to technological change in various types of enterprises.

During our visit to Chile, we found evidence of some important government initiatives with respect to the technological needs and performance of some sectors of the economy. For example, we learned of a six-month study by a Comisión Nacional de Nuevas Tecnologías de Información y Comunicación which will seek to identify public policies and private initiatives that are needed to promote the rapid and widespread

Table 19. Attitudes to technical change of different classes of enterprise.

Large enterprises		Small- & medium-scale enterprises	
Multinational corporations	**National companies**	**New technology-based companies**	**"Traditional" SMEs**
Dependent on extensive inputs from R&D in a wide range of fields to retain competitiveness.	Usually underinvest in R&D. When they operate in protected markets, they show little or no inclination to innovate.	R&D essential to their existence. Many were created by former university researchers.	Usually unable to identify their own technical deficiencies or needs; have zero contact with R&D.
In addition to having in-house R&D capacity, they are increasingly involved in R&D consortia involving other enterprises; they have wide range of relationships with developed (and some developing) country universities in selected fields.	May have some contact with government R&D facilities, mainly for trouble shooting. Prefer to purchase or import technology rather than to engage in its development.	Likely to have good contacts with universities since they are in fast-moving fields. In fact, the greater their in-house R&D capacity, the more sophisticated is likely to be their strategy for dealing with university researchers.	Rarely have any contact with their national S&T community unless the local R&D institutions have made special efforts to get in touch. Usually rely on suppliers for technology and information.
Highly developed internal systems for technology transfer among affiliates. Continuous training used to upgrade staff within company.	Technology importation done as discrete contractual arrangement not as part of a continuing relationship. Rely on universities and others to train staff.	Many sell technology rather than manufactured products.	Usually use outmoded technology; resistant to change. Need access to proven technology.
Generally have good links between R&D function and production.	Often have poor to non-existent links between R&D and production; may have problems in managing technical change.	R&D is the heart of the company which lives or dies by its ability to commercialize new technology.	Have limited access to capital for upgrading their technology. Likely to have difficulties in managing technical change.

Source: Updated from Mullin, J. *Technology Policy and University-Industry Links*. Paper prepared for IDRC and for presentation at an international workshop on "Technology, Commercialization and R&D", Bangalore. India, June 1992. (Published in the Series "Technology, Innovation and Commercialization" by Southbound Publishers, Penang, Malaysia, July 1993.)

expansion of information networks in Chile (*Correo de la Innovación*, Año II, No 5, Julio-Octubre 1998, p. 1). Resulting initiatives will provide clear opportunities for Chilean companies to build on their considerable success in helping Chile's banking system introduce modern electronic-banking methods into the country over the last decade. A major initiative in the area could serve both to increase access to information, and to promote further technological innovation in Chilean firms.

VIII. The development and use of human resources in the national system of innovation

Learning and the national system of innovation

In other countries, the importance of the education system in an NSI is recognized in a number of major reviews of national, post-secondary education systems. These particularly focus on the importance of the development of the individual for flexibility, adaptability and continuous learning. As well, reviews emphasize the importance of the role of the individual in contributing to the capacity for organizational learning and knowledge-access. A recent Australian report observes:

> Higher education has a distinctive and important role to play in the learning society. In particular, higher education should, whatever form it takes, whether it be professional, technical or liberal, open, nurture and refine minds, and create independent learners. It should enable individuals to grow intellectually, to achieve personal fulfillment, and to contribute fully and at the highest levels to society, the workplace and the nation. (Committee to Review Higher Education Financing and Policy 1998)

It is also a fact that education, economic and social policies are now deeply interdependent. One cannot be developed in isolation from the other. In a special theme chapter on the "Knowledge-Based Economy" in its 1996 S&T Outlook, OECD underscored the importance of government policies that link education/training and the economy:

> ...to promote broad access to skills and competencies and especially the ability to learn. This means providing broad-based formal education, establishing incentives for firms and individuals to engage in continuous training and life-long learning, and improving the match between labour supply and demand in terms of skill competencies.
>
> Others have stressed the link of education/training and the quality of life:
>
> Policies in one area will inevitably affect others... Deficiencies, or deficits, in human development affect not only the economic bottom line in terms of productivity and growth, but also the quality of life: physical and mental health, capacity to raise well-adjusted children and ultimately the country's capacity to maintain social order and cohesion. (Government of Canada 1996)

The challenges of human resource development in Chile

In the limited time available to explore the formal and informal systems for human resource development (HRD), along with gaps in competencies and skills, we heard some views that touched on a wide diversity of issues relating to HRD:

- Societal support for research requires an informed population who recognizes the benefits of a strong research system. Chileans do not possess a broad appreciation of the role of science, technology, and innovation in enhancing either the quality of life or economic development. This adversely affects the pipeline of people into S&T-related programs — and societal support for R&D more generally.
- Students entering post-secondary education come primarily from private schools. Therefore, there is a growing concern regarding the narrowness of the social base from which entry-level students are derived. This is especially true in programs such as medicine and engineering, for the social and economic consequences of this trend lead to elitism.
- The quality of Chile's primary and secondary school system, especially in S&T, was described as being uneven at best. Deficiencies in science teaching threaten the supply of young people with the capacity for and interest in research careers. It also diminishes the chance of women and other under-represented groups that aspire to attain entry to graduate school.
- The basic university undergraduate program in engineering takes up to seven years. It produces a high-quality graduate with a relatively narrow range of career options because of the high level of formal training. There is a wide divergence of opinion whether such an extended period should be required to complete the initial level of undergraduate training.
- Concern with the increasing number and diverse quality of post-secondary education institutions is leading to broader support for the notion of a national qualifications framework for post-secondary education.
- There is a major gap in the provision of technological training, and a concern that technical training is not valued in Chile. Too many of the emerging post-secondary education institutions appear to emulate the traditional university, rather than providing a broader diversity of education and training options.
- The production of masters- and doctoral-level graduates in Chile is low (40–60 Ph.D.s annually). While training abroad is encouraged and appropriate, many stressed the importance of increasing the quantity and quality of Chilean-based graduate programs.
- There is inadequate orientation to or capacity for technological innovation, technology management and technology transfer — in universities, technical institutes and the private sector. Many suggested the need for incorporation of

courses on technology management at undergraduate and post-graduate levels, as well as greatly expanded opportunities for professional development of those already in the workplace.

- The age distribution of university faculty was universally characterized as a major problem — in terms of both opening for new researchers and the research culture and value system. Incentives for retirement of existing faculty and attracting younger researchers into the university system were identified as key priorities.
- Major upgrading of the research competence of the existing faculty complement is seen as a priority. Of current faculty, about 19 percent hold a doctorate, and a further 27 percent hold masters' degrees.
- The recently introduced change in tax incentives for training of SME employees is highly regarded by companies and institutions, both for its direct training benefits and for the linkages that it is helping to forge between firms and post-secondary institutions, particularly in the regions.

These assessments reflect an accurate perspective of the evolving role of educated and skilled people and their knowledge in the NSI. OECD emphasizes that four types of knowledge are important. These are explored below with comments on their relevance to human resource development in Chile:

1. ***Know what*** — knowledge of facts or information. Most professions require formal education as a means of acquiring and updating facts and perceive the formal education system (including the post secondary education system) as being the essential supplier. In Chile, the health of that pipeline is seen as fragile and inadequate for continued supply of knowledge. Particular weaknesses are seen in technological training and S&T management. It is also adversely affected by the lack of a broad, societal S&T-awareness and culture, which constitutes the elite feeder-system to post-secondary education and faculty demographics.
2. ***Know why*** — knowledge of the principles and laws of nature. Such knowledge is more specialized, embedded in technically trained people in universities, technological institutes and, to a much lesser extent, firms. It is maintained through research. Firms, however, require access to such knowledge for advanced technological development. Normally, access to such knowledge is achieved through interactions between organizations, or through hiring of specific skills. This implies a culture of mutual respect between sectors, as well as some consideration of national needs in the building and evolution of research-capacity in universities and technical institutes. Programs such as FONDEF and FONTEC have made major strides in promoting such interactions. But there is little tradition of researcher-mobility among sectors. We were advised that in some

fields, a career in industry was seen as an abandonment of academic values! While promoting an exact match of demand-and-supply is neither desirable nor responsible, the current dissonance between Chilean needs and the capacities of post-secondary education systems is not productive.

3. ***Know how*** — the skills or capability to do something. Such knowledge is typically developed in technological and professional training, and even more frequently in on-the-job experiences in the individual firm. Clusters of firms may share "know how" and enhance it through industrial networks, in-house training programs or partnered training programs targeted to their needs. Alternatively, know how can be acquired through new hires. Access to technical and professional training programs and their recent graduates, industrial networks and local community economic development organizations underpin this type of learning. There is significant room for growth in this area, and the need was well recognized by those interviewed.
4. ***Know who*** — information about who knows "what" and "how." This is an increasingly important element of an innovation system, which underpins the capacity to know when and to approach, so as to access external knowledge and technology in a timely, relevant and efficient manner. This type of knowledge is the most internalized within an organization and considered a key part of its assets or intellectual capital. Until this type of knowledge capacity is built in the private sector, there will be a weak receptor capacity for adoption and adaptation of new technologies and for innovation.

In addition to the above assessments by those we met, an examination of the data on the post-secondary education system provided a number of additional insights that highlight and reinforce issues of concern.

The graduate-student population in Chile is less than 4 percent of the total student body, in sharp contrast with that of other countries — for example, in Canada there is a 13 percent level of continuation. While foreign graduate training in Canada may account for much of the difference, the attraction and retention of good graduate students is a critical element of a healthy research environment.

There are significant differences in the distribution of students by field of study at undergraduate and graduate levels. The two areas that show the most striking differences between study levels are:

1. natural sciences/mathematics with 4.8 percent of undergraduate degrees, but 24.6 percent of the graduate degrees; and
2. technology (including engineering) with 27 percent of the undergraduate degrees, but only 13.6 percent of graduate degrees.

The traditional strength of Chile's universities in the natural sciences is represented in this outcome. However, we believe that this is not a sustainable profile for development of the necessary human resource base for Chile's future needs, regardless of the level of training abroad.

Attainment of degrees per enrolled student is of the order of 10 percent, a figure that is low by international standards (compare with Canada at 20 percent, including all part-time students — and that rate would be close to 30 percent if part-time students were excluded). There is considerable variation in degree-attainment-rate among disciplines, with the highest level being about 20 percent for agriculture, health, and technology at the graduate level. But even this rate is low when considering that it includes master's students. We do not have information on the extent to which the rate reflects drop-outs prior to completion of the degree relative to the duration of time for completion. These data do, however, merit further discussion in Chile. Many countries are targeting reduction of the inefficiencies in the educational system from either drop-outs or undue duration of studies.

Table 20. Degrees by field of study in Chile.

	Undergraduate	Graduate
Agriculture	9.4%	6.9%
Arts and architecture	4.0%	3.0%
Natural sciences and mathematics	4.8%	24.6%
Social sciences	19.5%	22.0%
Administration/derecho	3.1%	1.1%
Humanities	3.7%	7.6%
Education	17.5%	10.4%
Technology	27.2%	13.6%
Health	10.7%	10.9%

The majority of the current research community was trained offshore. The quality of training, insights and contacts through that offshore experience have been a major asset to Chile. However, without a higher enrolment in graduate studies within Chile, the research environment will suffer. Students bring new ideas and they challenge conventional thinking. But given the concentration of research-intensive institutions in Santiago, there is limited choice for a student who should move from the institution at which the undergraduate training was obtained. Careful thought must be given to an aggressive program of graduate-student support that provides expanded opportunities for Chilean students to study aboard for a portion of their graduate program, and that can attract foreign students to study in Chile. Sufficient stable, multi-year support targeted at high-ability youth is required for this effort. At the same time, consideration should be given to reinforcing the development plans of a number of the regional universities that have the potential for stronger research performance.

We were also struck at how research training was considered training for a research career, rather than training through research for a broader set of career options that requires independent thought plus analysis of complex problems, including — but not limited to — academic positions. We do not advocate a move from research-based graduate programs, or the requirement for an in-depth investigation in a specialized area. Rather, we recognize the value of providing a range of educational opportunities within the core graduate education that will equip students for more diversified careers. This might include business management, technology management, or information technologies.

Training and the role of technical colleges

We have heard that the training of professional technologists — those skilled people with a practical rather than theoretical basis to their training — is relatively neglected in Chile, as it is in almost all other countries of the region. This should be a concern to policymakers since the internal levels of technological competence needed throughout firms are increasing. Thus, more and more entry-level positions need young people with a solid, basic-education in technology. Colleges provide one means of addressing this requirement.

While there is a relatively uniform understanding of the role of a university in the post-secondary education system, the distinction between a college and a university varies according to the country and often the region within a country. Thus, no precise definition is possible. However, in general, colleges are institutions rooted in their communities and designed to serve as the primary community vehicle for adult education and training. They normally have the primary mandate of responding to the training needs of business, industry and the public sector, and the educational needs of vocationally oriented graduates from the formal education system. In many jurisdictions, colleges offer diplomas and certificates, but not degrees. Their faculty is normally not engaged in long-range basic research, but may be active in applied R&D.

In many countries colleges play a vital role in offering adult education and employee updating, as well as in providing opportunities for training recent graduates from the formal education system, including programs such as technology, trades, applied and creative arts, health services, business, hospitality, and university preparation. These programs can be a stepping-stone to university education or, conversely, an opportunity for university graduates to acquire vocational skills that will be more directly targeted to the employment market. Partnership with the private sector in the design and delivery of course material is common.

Some Chilean post-secondary education institutions have trades, technology, and business training programs. But, in general, there appear to be relatively few institutions

targeted at the market for adult education and vocational training. A formal linkage between Chile and the Canadian community college system, which is designed to promote development of a Chilean College system, represents an outstanding opportunity to redress the gap. Some existing institutions may, in fact, find it advantageous to differentiate themselves from the larger group of institutions that play a more traditional university role in Chile.

Introducing new technological skills into enterprises

One of the far-reaching and significant consequences of the pattern of rapid technological change which now characterizes the global economy is the never-ending pressure on firms to have increasing levels of skill and competence manifest within their employees. This thrust has two important effects. It increases the necessary skill level for entry-level employees, and it demands a continuing process of technological upgrading for all employees in a firm.

To give an idea of how the workplace demand for knowledge and skills is changing, we use an example (Ontario Premier's Council 1990, p. 8) from an industrialized country. It compares the educational requirements of existing jobs in the late 1980s with those of new jobs being created in the last decade of the century. While the estimates shown are for a developed region of the world — the province of Ontario in Canada — the trend will be similar in all countries participating in the global economy.

Table 21. The educational requirements for existing jobs in Ontario in 1986 and of new jobs expected in 1986–2000.

Years of education and training	1986 current jobs (%)	1986–2000 new jobs (%)
17 or more years	23	49
13 to 16 years	22	15
12 years (high school)	10	3
Less than 12 years	45	33

The significant shift to jobs requiring extensive education has important consequences for the planning of higher education.

In Chile, we understand that there is a tax-incentive program that encourages employers to offer training to upgrade the skills of their employees. Recent amendments to regulations have made the incentive more accessible to SMEs. These are important steps in the right direction. Government should ensure that it has an adequate evaluation mechanism in place to track the extent to which the incentive is achieving its goal. Employers need to recognize that it is in the interests of the competitive position of their firm that all employees adopt an attitude of "life-long learning" and that the firm provides opportunities for that need for learning to be met.

The availability of research management skills

One of the dominant features of the research community in Chile is the small size of the typical research groups in most of the institutions we visited. Only in a few locations were we conscious of attention being paid to the tasks of research management. The skills involved are complex. This is even more true when applied to the process of technological innovation, with its requirements of blending the contributions of science, technology and the skills of the marketplace. However, as in almost all countries, Chile operates on the unsubstantiated hypothesis that the best researchers are automatically the best research managers. It is our belief that there is an established pool of knowledge in the area of research management that both can and should be accessed by those Chileans who will undertake leadership roles in Chile's NSI.

We have heard that the education available in Chilean business schools in the major universities is of good quality. Chile's economic success attests to this. We are also aware of — and impressed by — the fact that a group of Chileans from the Department of Industrial Engineering at the Universidad de Chile and from the four largest forest-products companies in the country became, earlier this year, the first Latin Americans ever to win the prestigious Franz Edelman Award for Achievement in Operations Research and the Management Sciences' awarded by the US Institute for Operations Research and the Management Sciences (*Correo de la Innovación*, Año II, No 5, Julio-Octubre 1998, pp. 38-40). It would be appropriate, therefore, to identify groups within this pool of talent who could develop courses on research management for those who will perform this function in both public and private institutions.

In the competition for institutional development funds under the Ministry of Education's MECE program for higher education, it would be useful for a specific invitation to be made for proposals in the area of Research Management.

Rejuvenation of the research community

Throughout this paper, we have explored concerns with the aging of the research community and the lack of scope for new researchers to develop strong independent programs early on in their careers. It is clear that no single program or action will tackle the complex mix of factors that have contributed to what is now a very real problem of demographics. The potential need for expansion of the research-active community adds to the existing challenges. Chile needs a sensitive portfolio of targeted policies and programs, probably with CONICYT as the main delivery arm. Also needed are strong partnerships with tertiary education-providers, to provide a smooth transition to a more balanced demography in the research community, and to optimize the benefits from an influx of new research talent.

Table 22. Examples of policies and programs targeted at improving the system capacity to introduce new, younger researchers.

Issue	Examples of incentive policies and programs
Interesting young people in a career in research	• Role models — researchers visiting schools (primary/secondary school system) • EXPLORA-type programs of S&T awareness (community targets) • Business-education partnerships — high-profile awards programs (private-sector involvement) • Undergraduate-student research awards in universities, technical institutes and industry
Support for graduate studies	• Ensure stipend is adequate for tuition and living expenses • Dual support mode — provision of competitive awards and support for student through research project • Strategic balancing of national and international awards over time and by field • National awards provide both units of study and travel abroad (including travel costs) • Rewards for research-training in tenure- and advancement-systems • Explicit recognition of the value and cost of research training in project funding • A limited number of prestigious awards that carry research support funding as well as stipends • Postgraduate studentships tenable in industry (joint supervision between university and firm) • Faculty developmental program — to promote upgrading of existing faculty
Opportunities for post-doctoral studies	• Competitive program of post-doctoral awards tenable abroad, with incentives to return to Chile • Faculty developmental program — upgrading of existing faculty through post-doctoral fellowships • Industrial post-doctoral fellowships (tenable in industry) • Program for attracting foreign post-doctoral fellows to Chile
Attracting new faculty	• A national commitment to R&D in the context of a broader S&T innovation policy and S&T culture • Reasonable prospects for receiving funding as new researcher (CONICYT) • Institutional commitment to R&D through institutional strategy, R&D office, direct funding (institutional) • Adequate salary levels and prospects (institutional and national) • Incentive programs that provide time-limited salary support and research funding for new hires (competitive)
Supporting new researchers in their research	• Selection criteria tailored for new researchers competing for funding (existing programs) • Flexibility in program requirements to allow new researchers to tap into programs for fast start-up on appointment • Special programs targeting new researchers, especially women and those in regional institutions • Program offering competitive opportunities for start-up research infrastructure targeted at new researchers
Private-sector career opportunities	• Industrial post-doctoral fellowships (tenable in industry) • Programs that provide salary support and/or supplements for university faculty to work in industry • Incentives for researchers in the private sector to supervise graduate students

We add one cautionary note from the experience of other countries. Major perturbations in highly qualified personnel hiring requirements (what is sometimes called feast-or-famine hiring) can induce long-term problems, especially if large numbers of foreign nationals are imported to fill gaps. We advocate a measured, long-term approach that anticipates needs and moderates fluctuations.

In Chapter V, we identified six particular aspects of the human-resource pipeline that would be appropriate targets of new policies and program incentives for a balanced approach to the challenge of rejuvenation and expansion of the research community. We want to stimulate discussion within the community on what types of actions are most relevant to current and projected needs. Therefore, we offer an overview of the types of initiatives other countries have used to tackle comparable problems in Table 22. There is no single silver bullet that will provide the desired outcomes. Most countries have found that a portfolio of policy and program tools that is carefully designed to address specific problems at each level of the human-resource "pipeline" is most effective. Careful monitoring, adjustment of policies and programs in an ongoing way, and periodic restructuring is required.

We are convinced that the government would receive broad support for the introduction of programs and policies targeted at promoting rejuvenation of the research community.

The Ministry of Education's program on quality and equity in higher education

We were informed of a number of initiatives being planned in the context of MECESUP to improve both quality and equity in higher education. The program is expected to cost approximately US $240 million over five years, and includes a loan from the World Bank. The current plans for its use tackle a number of the significant issues identified in this report and provide an exciting opportunity for major evolution in the education system. In areas directly relating to higher education, we were advised of these plans.

- Introduction of a voluntary quality assurance (QA) system into the post-secondary education system in both universities and technical colleges. While this would be directed initially at the undergraduate level, it is expected that there would also be application for post-graduates. CONICYT is likely to assume responsibility for this. Ultimately, eligibility for state funds is likely to be contingent on compliance with this voluntary QA system.
- An institutional development fund will replace an existing competitive program for institutional projects. Project proposals that are significantly larger and more long-range in nature will be adjudicated in the context of institutional plans, taking into account criteria for national development.

- While major funding will be directed toward undergraduate education, within the institutional development fund consideration is being given to a number of R&D related initiatives:
  - upgrading the research competence of faculty (existing and new hires), including the possibility of a salary-supplement for new appointments;
  - improving stipends for Ph.D. students, as well as funds to increase the mobility of graduate trainees;
  - funding for major equipment;
  - creating interdisciplinary research and small centres of concentration/excellence;
  - upgrading the information technology and communications systems, especially in order to ensure on-line access to primary research literature; and
  - accrediting of the post-graduate training system.
- Studies are also underway to show how the state can move from the historically based funding system to one that is outcomes-oriented. Starting in 1998, a small portion of these funds will be allocated to post-secondary education institutions based on the educational results produced to date, while working on improved institutional plans and performance indicators.
- Resources that will enhance technical training are being proposed, such as the proposed agreement with the Canadian College system.

We were impressed with the strategic thinking that had gone into development of these initiatives. Together with a concerted effort to address the introduction of younger researchers into the active-research community, this list of initiatives will target many of the "know what" and "know why" elements of Chile's knowledge needs. But there remains a need for more attention to the "know how" and "know who" aspects — and in particular, the means of promoting mobility between post-secondary education institutions and firms. Notwithstanding the advances of recent years, there remains a real cultural barrier between these sectors in some disciplines.

Many countries have introduced programs that tackle this interface directly — from the undergraduate to the faculty level. And, although many of these initiatives are comparatively low in cost in the overall scheme of things, they have resulted in significant cultural change. While the design of programs and incentive structures should ultimately be a matter for Chile, some examples of successful initiatives from other countries are cited in Appendix 5.

IX. Institutions providing the infrastructure for the national system of innovation

Standards and metrology

Chile's national standards body, the Instituto Normas Nacional (INN), is attached to the Ministry of the Economy. Although owned by the State, it is permitted to earn contract-income that is derived from its accreditation services. There is a national accreditation system that includes laboratories licensed by INN to provide certification from universities, the technological institutes, and the private sector. INN also incorporates a Metrology Unit.

INN is a member of COPANT, the umbrella standards body for the Americas. One of its mandates is to facilitate the development of standards of interest to the region. Standards are an increasingly important element in a strategy for national competitiveness, as well in promoting safety and quality of life. The introduction of technical barriers to trade, as a strategy in international commerce, makes INN a highly strategic body. The norm for national expenditure on standards for industrialized countries during the 1980s was about 0.2 percent of industrial output. (This figure is likely to be revised upwards in the face of globalization and WTO prescriptions.) For now, these figures represent a Chilean investment of approximately US $80 million per annum.

Intellectual property

Chile belongs to the World Intellectual Property Organization. Chile's intellectual property (IP) regime is basically compatible with international norms. However, some continuing deficiencies in patent protection have kept Chile on the United States' Trade Representative's Special 301 watch list since 1989. The industrial property law promulgated in September 1991 substantially improved Chile's protection of industrial patents, but it falls short of international standards. The law provides a patent term of 15 years from the date of grant, as opposed to the international recommendation of 20 years. It also does not consider plant and animal varieties or surgical methods to be patentable, and does not provide pipeline-protection for pharmaceutical patents filed abroad before promulgation. Nevertheless, for the first time in Chile, the law regulates the relationships between employee-inventors and employers. It defines the way in which rights to an invention should be apportioned. The new law also created a special Court of Appeal for industrial property matters.

Piracy of video and audio tapes, as well as other copyright infringements, has been subject to criminal penalties since 1985, and recently Chilean authorities have taken aggressive enforcement measures against pirates. Efforts to enforce intellectual property rights in Chilean courts have generally been successful. In the mid-1980s, the software piracy rate was believed to be around 90 percent but has decreased to around 68 percent, believed to be the lowest rate in Latin America. Nevertheless, Chile's software developer's association has estimated that some US $74 million worth of software was pirated in Chile in 1995. A social conscience regarding the protection of IP rights is not well developed. Copyright protection is 50 years.

The advances Chile has made on intellectual property protection facilitates the applications of The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) standards. A new draft law is now being studied by the Ministry of Economy to raise these standards. Adherence to TRIPS will probably mean increasing the public budget to support enforcement activities. However, patentors and other users of the IP system could support a percentage of costs.

The main impediment to successfully implementing an effective intellectual property regime is the low commercial value placed on IP by Chileans. In response to the 1991 IP law, applications for Chilean patents by non-residents rose steeply from 637 in 1990 to 2 024 in 1996. During the same period, applications by Chilean residents rose only from 161 to 359. The patenting rate (about 0.4 patent applications per 10 000 inhabitants per annum) is comparable with that of Spain (0.6), but much lower than that of OECD countries (Japan = 26; Germany = 5). There is an extremely low rate of application for US patents (9 were granted in 1997).

The lack of emphasis on patenting in the Chilean research system is worrying. Recent evidence (Narin et al 1997, pp. 317–330) demonstrated by rates of citation of research articles in US patent applications indicates that there is an increasing connection between high-quality scientific research and innovation. FONDECYT, FONDAP and even FONDEF are currently not sensitive-enough to difficulties experienced by researchers in reconciling the bibliometrically-based evaluation criteria for funding with the requirements of patenting their work.

Telecommunications and Internet infrastructure

As in many Latin American countries, telecommunications companies in Chile were state owned and operated in a monopolistic environment until recently. Two companies served the whole country: Entel, the long distance carrier, and CTC, the phone company (which was not allowed to install its own long-distance facilities). A few exceptions were permitted, for example in the South of Chile, where the private operator Telefónica del Sur provided a service. In 1985, Entel and CTC were sold to the private sector and

limited competition was allowed in long-distance services. This was the starting point of a series of private investments in the telecommunications sector that promoted several advances in just a few years.

Three digital data networks were established in Santiago in 1990, all of which expanded rapidly. Chile is now the only country in the world to have a 100 percent digitized telecommunications service. Cellular phones have been available since 1989 and their use has been widespread since 1992. Four companies offer their services nationwide.

In 1994 deregulation was pushed to the limit when long-distance services were opened on a free competition-per-call basis. This has now been extended to local systems. The customer can choose the carrier for any call locally, nationally or internationally.

Deregulation has produced certain effects:

- dramatic reduction of prices;
- investments in fibre-optic infrastructure have created an impressive telecommunications backbone in the country; and
- significant investment from abroad.

Chile currently has a telecommunications infrastructure and portfolio of services to rival any in the world. It is a crucial contribution to the level of competitiveness of the Chilean economy.

Chilean access to the Internet goes back to 1986 and the birth of REUNA at a meeting of computer science departments of Chilean universities. Four departments decided to start a UUCP network and IBM donated hardware, software, and leased lines to establish an SNA network among them. These initiatives were gathered under REUNA, and by 1987 an e-mail gateway had been established, with the network including universities from Antafagasta, Concepción, Valparaíso, Santiago and Valdivia. In 1991 the group of universities (coordinated by CONICYT) established an IP network with financial assistance from FONDEF, whose idea was to contribute to the development of an infrastructure that would benefit not only the universities but also the private sector. REUNA's commitment to FONDEF was to generate income from the private sector so that the annual rate of return was at least 13 percent, a target that has been well exceeded.

REUNA's connection to the Internet was established on January 2, 1992 and the first year of operation was funded by CONICYT. The commercial start of REUNA was 1993. After a slow beginning a monthly growth-rate in traffic of 13 percent was reached in 1993, which has risen to approximately 20 percent.

Although there are now other Internet service providers, REUNA is still carries the largest volume of traffic, 95 percent of which is international. Service pricing involves a mixture of volume charging and flat rates. No charge is made for e-mail.

The creation of REUNA has been crucial to the development of Chile's Internet and ranks as one of the singular successes of the FONDEF program. FONDEF has succeeded in stimulating collaboration between academic researchers and the private sector in an absolutely key area. The result has been that Chile now has the largest number of Internet hosts per unit of population in Latin America.

Libraries

Some university libraries in Chile are relatively well resourced, from the perspective of IT infrastructure as well as book stocks and access to journals. In comparison with libraries in other countries of a similar level of development and with which we are familiar, Chile's appeared well supported. Larger universities keep upwards of 1 000 journals on site, and have access to standard international stocks via systems such as Uncover (17 000 journals) by means of the Internet. In general, we were informed that universities cover the costs of ordering photocopies of articles. At US $25 per article, this can amount to a cost of US $500 000 per annum for an average-sized university. There is room for improvement, however, in the regional rationalization of library services. It is considered easier to order an article via Uncover than it is to check electronically if another institution in the same city stocks the relevant journal.

This commitment to an excellent library service is not surprising in a research system that emphasizes publication to the extent that Chile does. Nevertheless, it is heartening that some university authorities have had the foresight to invest in modern infrastructure and are sensitive to the needs of researchers in this regard

Major facilities for big science — the observatories

Chile is extremely fortunate — probably more so than any other country at an equivalent stage of development — in possessing the natural conditions to enable it to attract major international scientific infrastructure. The only developing countries which have attracted equivalent scientific interest are those in the Middle East and Africa, which are rich in archaeological and cultural deposits. Unfortunately, such interest is not matched by infrastructural investment.

Chile has hosted scientific events at international astronomical observatories in the Atacama Desert for over 30 years. These include the Cerro Tololo Interamerican Observatory in La Serena, the European Southern Observatory (ESO) at La Silla, and the Carnegie Southern Observatory at Las Campañas. New optical telescopes are being constructed at Las Campañas (the Magellan telescope), at Cerro Pachon (the Gemini

Southern Telescope, which has a Northern Hemisphere counterpart at Mauna Kea) and at Cerro Paranal (the ESO Very Large Telescope). The Millimetre Array (MMA), which will extend high-resolution radio astronomy to millimetre wavelengths, is to be located at Llano de Chajnantor.

The Chilean Government has exercised great wisdom in facilitating low-cost construction by granting duty-free and tax-free status to the observatories. In general, the boards of the observatories have granted Chilean astronomers 10 percent of the viewing time in return for the use of the sites and in recognition of the positive attitude of the Chilean government. Chile itself does not contribute directly to construction costs.

On average, five nights of viewing generates sufficient data to keep an astronomer busy for a year. The total amount of viewing time currently available to Chilean astronomers is about 350 nights. This indicates a saturation level of about 70 astronomers, assuming limited collaboration. The fact that there is only about 30 Chilean astronomers means that Chile has not yet made sufficient use of its unique opportunities.

Citation rates for articles published by Chilean astronomers are higher than those published by other types of Chilean scientists. If Chile wishes to be at the cutting edge of world knowledge-development, there is no more promising area than astronomy for it to achieve this. The fact that the astronomers play in a different league to other Chilean scientists is underscored by the relative costs of the equipment to which they have access. FONDECYT currently has an equipment ceiling of about US $40 000, but the observatories cost at least a thousand times as much.

It is encouraging to note that in the most recent agreement to build another foreign-financed telescope in Chile, the government has included a provision in the contract to ensure the participation of Chilean engineers in the construction and infrastructure activities. Gaining access to challenging assignments will be an advantage to the engineering profession in the country.

Analysis of issues within the national system of innovation

X. Emerging issues

Institutional governance

In recent years in Chile there has been considerable experimentation concerning the financing of technological institutes and the adaptation of financing instruments to meet changing objectives. But we have seen little evidence of consistent thought being given to the governance structures of either institutes or funding bodies. At a general level, we are struck by the almost complete absence of board members from the private sector on the boards of institutes such as INTEC, or on the decision-making body which approves FONDEF grants. Furthermore, in a recent CORFO document (Marco de Política para el Sistema de Institutos CORFO 1998) discussing policy for the five CORFO institutes, the description of the functions of the boards is very cursory, and there is no discussion of their composition. Of the list of board members mentioned, only one is positively identified as coming from the private sector.

In Chapter V, we have noted the varied history of the Consejo Asesor attached to CONICYT. We made particular proposals concerning the introduction of a management board into the governance structures of CONICYT.

In many countries, most technology institutes have a corporate system of governance to the extent that the senior decision-making body (at least in theory) is a board or council. These bodies are equivalent, in many ways, in terms of their roles and responsibilities, to a corporate board of directors. In most, members are drawn heavily from the private sector and are appointed by the minister responsible for the technology institute. What varies extensively are:

- the extent of real independence from management and decision-making authority demonstrated by the Board of any particular technology institute; and
- the extent to which special, additional arrangements are made to provide for the governance of the constituent institutes, programs, units or divisions of the technology institute.

The traditional board of a multisectoral technology institute will usually have private-sector representatives from some or all of the sectors in which the technology institute is active. The numbers involved will depend on the size of the Board and the breadth of the sectoral scope of the technology institute's program. The overall policy objective of including private-sector members on boards has been to give clients a real voice in setting institutional priorities. The practice also brings a practical understanding

of the constraints within the markets that the institute is attempting to serve into its strategic thinking.

In the past, many such boards have tended to be captives of senior management, with their role being to discuss and approve proposals brought to them by management. They would not have much of a role in initiating actions and rarely, if ever, would they act to enforce the accountability of management for its actions. Most such boards would not have the right to hire or fire the chief executive. This pattern is changing and governments around the world are establishing terms of reference for boards that give them significant powers and accountability.

In addition, in some cases similar governance systems have been created at the level of the component parts of the main organization, to allow closer interactions. For example, in November 1992, Canada's National Research Council (NRC) put in place a new "Policy for Council Advisory Boards" which allocated significant duties and responsibilities to "Institute" Advisory Boards, most importantly the duty to:

> ...provide an effective mechanism for the participation of clients and collaborators in the definition of priorities and direction of the institute.[9]

These boards have their own direct-reporting route to NRC's governing council. They do not report to — or through — the head of the institute.

Other less-formal mechanisms have also been used to permit clients to influence the program directions of institutes. There have been cases where institutes have created "Industrial clubs" through which, in return for an annual membership fee, companies were offered specific benefits and a means of voicing views on the institute's research directions by participating in an annual research symposium. During these, the institute presents its planned research program for the following year for discussion. In a similar vein, INIA has a system of involving farmers in discussions of research directions.

We believe that the ongoing discussion of the evolution of technological institutes and of technology funds should, in future, pay more attention to the definition of the strategic management roles of boards and to their composition. This will ensure good private-sector representation.

The need for prioritization

Chile has developed an admirable culture of economic competitiveness. Guarantees and protectionism have been largely eliminated from the system. The basic assumption is that the market will ultimately ensure that Chileans receive quality services at economic rates and generate sufficient growth to eliminate poverty. This tradition of self-reliance

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[9] The major component parts of the NRC are called "institutes." NRC. November 1992. Policy for Council Advisory Boards, Ottawa. p. 2.

and rejection of entitlement has been transferred to the administration of S&T, where, to an almost religious degree, all funding proceeds on the basis of finely regulated competition. By and large, especially for FONDECYT and FONDEF funds, the overwhelmingly dominant criterion is stated to be that of scientific excellence. No field is favoured *a priori*, and the predominance of a particular discipline over others apparently proceeds simply as a result of a concentration of excellence.

One cannot argue with the remarkable economic success achieved by Chile using basic market principles. It is tempting simply to affirm that an S&T system based on competition will inevitably result in similar high levels of achievement. The question to be asked, however, is whether the competition underlying Chilean S&T policy has anything to do with a real economic market. Innovation is part of a competitive strategy, not merely an analogue of it. Given the strategic and long-term nature of research (even in fields close to the market, lag times of several years are normal), innovators need to anticipate markets and to choose areas where they have a potential advantage. If funds to promote innovation are to work optimally, they should also be able to anticipate strategic areas. The beginnings of such an approach are to be seen in FONDAP. The large astronomical observatories offer a huge advantage to Chilean astronomers.

It would also not be wise to eliminate the well-run competitive funds in favour of a system where the say-so of a "wise" council would determine what was deemed strategic. The result would almost certainly be cronyism, bitterness, and demoralization. Chilean scientific culture values transparency and clearly stated criteria. A way to arrive at such criteria, mediated naturally by competitive rules, would be to conduct a Technology Foresight study in Chile. In such a study, a very large section of the S&T community would itself be involved in determining strategic foci. The programs and projects that flowed from this process could not be labelled as arbitrary.

Most scientists begin their research careers in a somewhat mundane rather than visionary way. They work on particular topics because their doctoral supervisors offer them — and not because they are drawn to them out of nowhere in some compelling fashion. Moreover, they choose their doctoral supervisors as much for personal as for scientific reasons. In a nutshell, it can be argued that, at a personal level, the topics of interest to individual scientists are rarely not subject to change. The strategic choices can, therefore, be made without affecting the quality of the science. In a country like Chile, where the availability of resources is not high, these choices need to be made to give the most promising areas an appropriate critical mass.

Technology for small- and medium-scale enterprises

When we were in Chile, we participated in many discussions that acknowledged both the importance of SMEs[10] in the creation of employment and their relative inability, in most cases, with respect to their capacity to manage technical change. We also heard of a small number of encouraging examples of the creation new, technology-based enterprises, sometimes designed to exploit technologies developed originally in a university setting. However, we did not have an opportunity to look into the present state of SMEs in general, or their capacity to manage technological change in particular.

Given this lack of first-hand data, we will offer first some general views on the needs of SMEs and then discuss some experience in Latin America and in other developing countries that might shed light on approaches worth considering in Chile.

An initial study in Chile

How to promote innovation in enterprises of all sizes, but particularly in SMEs, is high on the agenda of CORFO and of the Programa Innovación Tecnológica. The most detailed study of innovation in Chilean industry of which we are aware is that covered in the report "Innovación Tecnológica en la Industria Chilena: Análisis de una Encuesta", published in July of 1997 by the Subsecretaría Ejecutiva del Programa Innovación Tecnológica as a result of a survey conducted in 1995 by the Secretaría with the Instituto Nacional de Estadísticas.

The survey dealt with the involvement of Chilean firms in one or more of the activities relating to product, process or management innovation. It covered firms with ten or more employees spread across eight sectors of manufacturing industry. One important finding was evidence that there was significant innovative activity in at least 20 percent of the surveyed SMEs. This being said, there was also an indication that there was no innovative activity recorded in more than half of the small enterprises in the sample. Of significance to the present report was the finding that:

> The survey demonstrates the very weak relationship that exists between industrial establishments and the scientific and technological establishments in universities and the public sector. It provides evidence of a structural separation between the manufacturing industry sector and the system of S&T institutes which are mainly oriented toward serving productive sectors closer to the exploitation of natural resources. (Subsecretaría Ejecutiva del Programa Innovación Tecnológica 1997, p. 38)

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[10] We define "small" as "having fewer than 50 employees," whereas "medium" has "between 50 and 200 employees."

Unfortunately, we know of no comparable study of the resource industries which indicates the extent to which technology institutes are linked to innovation. In some cases, such as salmon production, the linkages are clearly crucial. It would be worthwhile to document that case and to undertake a more general survey.

Some experience from around the developing world

At a more general level, careful consideration of the overall needs of SMEs leads to the conclusion that their most pressing, continuing needs can be summarized under five broad headings:

1. finance of all kinds, including finance for activities related to the promotion of technical change;
2. markets and market information;
3. improved management skills and systems, including those necessary for the management of technical change;
4. improved training for all of their employees, in particular to allow them to keep up with changing demands in the marketplace (particularly for improved quality and service) as well as changing practices and technologies in the workplace; and
5. best-practice technologies, where "best practice" is defined in terms of the acquiring enterprise's capacity to absorb and manage the technology in question.

This set of needs can then be used to provide a demand-side framework for considering government support policies. Innovation policy must address each of these broadly defined needs. It needs to do so in the context of the evolving rules of international trade as established by the WTO.

Recent work in Colombia (Mullin Consulting Ltd., et al 1996) categorized the predominant negative attitudes and approaches of SMEs as having a:

- lack of tradition in developing or continuously improving products and processes;
- lack of understanding of technological needs in an open market;
- lack of understanding of management needs;
- chronic shortage of funding (long-term financing or short-term cash flow);
- lack of ability to cope with the impact of the opening up of the domestic market to freer forms of trade;
- lack of understanding of the opportunities that freer trade presents;
- absence of any tradition of seeking advice;
- acute lack of trust in government programs; and a
- lack of tradition of working together.

This list is similar to one assembled in an earlier study of SMEs in Malaysia, where the main findings were:

1. Although they appear to be aware of a wide range of manufacturing and management technologies, Malaysian SMEs only make use of a very limited range of such technologies.
2. Because of the generally low level of the SME manager's education, they are unable to determine their real technological needs. Therefore, they do not seek technological solutions to their business problems.
3. They face a variety of marketplace problems which can be addressed through improved access to technology. Also, SMEs display interests in a wide range of business opportunities that have definite technological relationships.
4. They display a generally low level of awareness of technological assistance that is available from the public-sector SME support institutions. Thus, they do not consider these institutions as significant sources of technological assistance.
5. SMEs appear to acquire most of their technologies from private-sector sources such as machinery suppliers and other companies.
6. Although the number of SME support institutions in Malaysia is quite large, very few of their programs involve technical consulting. Most of the activities and programs are generalized and do not address specific problems of firms.
7. One of the major gaps in the activities of SME support institutions is the lack of a company orientation. Technological assistance offered is too "function-focused" as opposed to being "enterprise-focused."
8. The problem of SME access to technology from their support institutions is compounded by the fact that most have insufficient outreach programs and expect SMEs to come to them.

The similarity between the findings of these two studies, and of others like them, supports the idea that there are a set of generic attitudes and strategies relating to the acquisition of technology common to SMEs around the world, in both industrialized and developing countries. We heard nothing in our interviews to suggest that the approach of Chilean small enterprises is markedly different from the patterns described above.

Access to existing technology by "traditional" SMEs

In countries that do not have an effective industrial extension service, traditional SMEs primarily gain access to technology through:

- contacts with equipment or materials suppliers;
- contacts with customers, particularly when the SME is a regular sub-contractor to a larger enterprise (this approach to providing technology to subcontractors is particularly well-developed in Japan); or

- access to patent literature concerning expired patents. This strategy, using specialized foreign firms as intermediaries for the literature search, was a strategy identified in a study of the practices of a number of Colombian firms. It requires that the firm have some in-house technical expertise in order to be able to assimilate and use the information obtained.

This statement on SMEs is generally consistent with the findings, with respect to sources of innovation, of the study by the Programa Innovación Tecnológica cited above.

In countries which have an established industrial extension system (for example, Canada[11] and Singapore) then the options are much wider. The existence of such services in a growing number of countries is testimony to the growing recognition that most SMEs need external assistance in defining their technology needs. They also need help in obtaining access to technologies which can meet those needs in a commercially-viable way. Both Colombia and South Africa at present are working through the problems of designing and implementing such a service.

While there are considerable successes to be seen in the operations of several industrial extension services, it needs to be acknowledged that they work most efficiently and effectively when their clients have some measure of in-house technical competence. In Canada's case, more than 75 percent of the clients of the IRAP system have some in-house R&D capacity. But less than one in three of all Canadian manufacturing SMEs fall into that category. A recent study (MacPherson 1997, pp. 127-144(18)) in New York State found that SMEs with well-developed internal technical skills exhibit above-average spending on external help. This suggests that the market for the services of technology centres improves as the average level of internal technical competence among their potential clients increases. A recent World Bank Report (World Bank 1997) published results of a study of some 167 technology institutions (TIs) designed to serve six industries of differing degrees of technological intensity[12] in eight different countries of different size and state of development[13], and has produced similar conclusions. This strongly implies that developing countries need to go beyond the experience and practices of industrialized countries as they attempt to promote technical change in the vast majority of their enterprises. Also, they must strengthen the contribution of public- or university-based technology centres in that process.

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[11] Information on Canada's Industrial Extension Program, IRAP, is available on the World Wide Web at http// www.irap.nrc.ca/irap/irap.html

[12] The six industrial sectors were foundries, textiles, auto parts, machine tolls, software, and polymers.

[13] The countries were India, China, Taiwan, Korea, Japan, Hungary, Mexico, and Canada.

Through CORFO and INTEC, Chile is showing a growing interest in understanding the potential contributions that might be made to Chilean productivity and competitiveness by some form of technology extension system. To this end, CORFO and INTEC are working with partner countries in APEC to promote an exchange of information and experiences. We believe that this exchange should be the starting point of a wide-ranging discussion between the government and SMEs that will lead to the design of a cost-effective system of technology extension.

Promoting an Innovation "culture" in Chile

It is somewhat of a surprise to find that Chile, after many years of opening itself up to participation in the global economy and welcoming foreign firms and investment, still does not see its capacity to innovate as crucial to its long-term economic well-being. Its firms, on average, still show low levels of involvement in promoting technical change — despite some real successes. There appears to be little political debate at very high levels concerning the country's record in innovation. (Perhaps the commissioning of this review is a signal that this latter gap is being closed).

There are some good efforts under way to attempt to change the present situation. At one level, the Programa Innovación Tecnológica, through its "Correo de la Innovación" is attempting to bring real success stories to the attention of Chilean enterprises. As well, the EXPLORA program operated by CONICYT is seeking to increase the understanding and interest of schoolchildren in matters of S&T.

One anomaly in the Chilean situation relates to what we have heard about Chilean trained engineers. We were told that the undergraduate training in engineering in the country is longer and more rigorous than that in North America, and that all Chilean engineers have a good grounding in the basic sciences. Furthermore, it appears that a high proportion of Chilean engineers quickly find positions in management. If this is the case, why is there such a low interest in promoting technical change in so much of the economy? Could the engineering profession in Chile, through its organizations, promote a discussion concerning changes needed so that innovation can be seen as a more critical variable in the competitive performance of firms? Should the profession also ask itself if training in entrepreneurship should be included among business skills provided to engineers in training?

We have seen how the President of Chile has taken steps to provide visibility for basic science in the country, most notably through the conferring of Cátedras Presidenciales on some leading scientists. Many other countries have devised prizes for innovation — in the United Kingdom, the Duke of Edinburgh's Award for Innovation has been in existence for more than thirty years. Chile should consider an annual prize for innovation, to be awarded by the President of the Republic at a ceremony that should

be highly publicized. The main element of the prize should be the public recognition that it confers rather than a monetary reward — perhaps winners should be permitted to use some distinctive mark on their products. CORFO and CONICYT could undertake a review of the mechanisms used in other countries to provide such recognition and make a recommendation to government.

The use of the government's purchasing power can be another tool to promote innovation throughout the economy. By setting performance standards for the goods and services it buys, government can encourage firms to be more innovative. The aim behind such a move would be twofold: to increase the quality of goods and services purchased; and to promote a climate of continuing incremental innovation in the country.

Support for the social sciences

The social sciences have had a difficult evolution in Chile, an experience shared by social science communities in much of Latin America prior to the widespread return of democratic governments to the region.

In Chile's case, during the period of military government, almost all social scientists and social science activities had to be located in NGOs and were supported by foreign donors. The irony was that the return of democracy led to a decline in foreign funding with no commensurate growth in local support.

Today, support for the social sciences is available through FONDECYT, but social scientists say that the volume of support is low. There is much controversy about the applicability to the social sciences of the norms and standards that FONDECYT has developed for use in evaluating activities in the natural sciences. A key issue is that of the role of Spanish-language publications as the vehicle for dissemination of the results of social enquiry. It is vigorously contended by social scientists in a variety of disciplines that "international publication" — which is the norm in the natural sciences — is not the norm in the social sciences which are much more culturally — and hence linguistically — sensitive.

The data published by CONICYT in 1995 (Table 23) do not suggest dramatically different success rates for applications for support by the different groupings of disciplines.

CONICYT's more recent tabulations of data[14] on the amounts of money spent within each group of disciplines shows that spending patterns changed appreciably in the years 1982–87. But, since 1988, they have been more or less stable with only the medical sciences continuing to make modest gains. Since 1988, the social sciences have received on average 8.3 percent of FONDECYT resources. Law, economics and

[14] Provided to the review team by the CONICYT Departamento de Información.

Table 23. Success rates and shares of approved FONDECYT projects, by discipline.

Disciplines	Success rate 1982–1995	Share of approved projects
Natural and mathematical sciences	44%	37%
Technological and engineering sciences	39%	14%
Medical sciences and technology	39%	16%
Agriculture and forestry	28%	8%
Social sciences	26%	12%
Law, economics and business	31%	5%
Humanities and fine arts	38%	8%

business together have averaged 2.1 percent and the humanities and fine arts have averaged 4.1 percent.

Experience in other countries shows that the successful linkage of the social sciences with other areas of science, in research dealing with broad issues of importance to society is helped when the responsibility for financing all areas of science resides in a single agency. Fitting into this category of broad research are topics related to population growth and its implications, including the problems of poverty, public health, many aspects of global change, smart cities and issues of the urban infrastructure. The task of breaking down the barriers among disciplines is difficult enough without adding a layer of barriers based on different institutional cultures and practices.

Given the past attention paid to the natural and mathematical sciences in Chile, we believe that it would be appropriate now to offer some political recognition and visibility to the social sciences as important contributors to national development in its widest sense. Among the activities that might be considered, we suggest three major improvements:

1. more participation from the social and human sciences on the Consejo Superior of FONDECYT, on the Comité Directivo of FONDEF and on a restructured management board of CONICYT which we have earlier proposed;
2. creation of a national task force focusing on future challenges and opportunities in social and human sciences research seen from a Chilean perspective; and
3. designation of additional themes under FONDEF and FONDAP that have strong social and human sciences dimensions. An important recent move by FONDEF, to open fields of technology development that are social rather than economic in their definition, may turn out to be a significant opening for new financing of at least some of the social sciences.

Health research

In 1987, an independent, international Commission on Health Research and Development (COHRAD) was established to review the state of health research in developing countries and to make recommendations for action. COHRAD found "a gross mismatch between the burden of illness, which is overwhelmingly in the Third World, and investment in health research, which is overwhelmingly focused on the health problems of industrialized countries." (Commission of Health Research for Development 1990, p. xvii)

Many developing countries neglect the research that is necessary to inform decision-making to improve the efficiency and effectiveness of health-related actions. COHRAD, therefore, recommended that all developing countries should adopt Essential National Health Research (ENHR), an integrated strategy for organizing and managing health-related research. ENHR is not a particular type or methodology of research, but a process whereby a country can direct its research toward its most pressing health problems. The ENHR strategy uses the full range of health research disciplines, including epidemiology, social and behavioural research, clinical and biomedical research, health systems research, and policy analysis. The innovation of ENHR lies in its emphasis on addressing priority health problems in an integrated manner using whatever range of methodologies is appropriate, and its commitment to linking research with implementation.

COHRAD recommended that the focus in health research should be shifted away from single projects with short timeframes toward an integrated, systematic program of health research for development. Of necessity, this type of program would entail a long-term perspective. COHRAD advocated that developing countries should invest at least 2 percent of national health expenditure and at least five percent of program aid for the health sector in research and research-capacity development.

This review found no evidence that ENHR was a topic of serious discussion in medical research circles in Chile. This is somewhat surprising, given the central role the philosophy plays in other developing countries such as Mexico, Brazil, South Africa and the Philippines. The apparent absence of this debate may well be due to the fact that no stand-alone bodies (such as INIA and FIA in agriculture) or even divisions within multidisciplinary bodies appear to exist for health research in Chile. Indeed, we have seen no statistics giving breakdowns for health-research expenditure either, although Chile's publication output in the area of clinical medicine is certainly impressive.

It is certainly high time that Chile develops its own health-research philosophy. Although the market-oriented approach of the PIT funds is admirable, health research is clearly also informed by criteria other than profit. The challenge will be to steer a path which reaches beyond simple bibliometric benchmarks, but which also recognizes the obligation to fund innovation in the context of a true national service.

XI. An innovation policy agenda for Chile

Our work has afforded us the privilege of gaining an overview of many of the facets of Chile's NSI. It has provided us with a wealth of information about the functioning of CONICYT and its main funds within this ever-evolving context. This experience permits us to highlight a set of issues that we believe should constitute the principal elements of a national discussion on the future evolution of innovation policy in the country. This is a debate that will be a necessary contribution to Chile's continuing insertion into the global economic community, and will provide the backdrop for the continuing development of CONICYT as a key institution of government.

In what follows, we briefly highlight these issues, which we put forward as an "Innovation Policy Agenda for Chile."

A focus on innovation

The time is ripe for debate on innovation policy in Chile to become much wider than a concern only of the Ministerio de Economía and its Programa Innovación Tecnológica. While PIT's work is valuable, it has not reached a sufficiently wide or senior audience. Yet it is dealing with the process which will need to become the basis of Chile's competitiveness in the years ahead.

Careful thought should be given to having all ministries consider how the promotion of innovative solutions to problems within their mandates could provide a general stimulus to innovation in the country. If government from the highest levels is seen to make innovation a priority, then the task of having the private sector invest more heavily in the process will become more feasible. If government does not provide a lead, then progress will be impeded.

We reiterate here that providing a focus on innovation is not a denial of the importance of investments in basic research. Rather, in our view, it provides a broader context within which to justify continuing investments in the pursuit of knowledge.

Issue: How can a national policy discussion be stimulated on the support of innovation?

Lack of policy framework and high-level structures to deal with innovation

Today, in the promotion of competitiveness of national economies, governments are discovering the need both to develop specific policies and programs to promote technological innovation, and to ensure that these policies are well-articulated with all of the other policies of government be they for education, health, international trade, environmental sustainability, or any other issue. To do this, governments must have a policy mechanism in place to both propose initiatives in innovation policy affecting all of government (and not simply the actions of an individual ministry), and to ensure that the mutual interactions of innovation policy and other government policies are explicitly considered.

We found no such executive mechanism in place in Chile today, but many individuals agree that one is needed. As we said earlier, any such mechanism must fit with Chile's political traditions and culture, and it should have the explicit support of the President of the Republic.

Issue: Will the Government of Chile assign a responsibility for oversight of innovation issues to a high-level mechanism within government?

Strengthening CONICYT as an institution as well as the operation of its funding mechanisms

We have paid particular attention to the performance of CONICYT and of its major funds, FONDECYT and FONDEF. We believe that the Minister of Education, on behalf of the Government of Chile, should undertake a restructuring of the governance of CONICYT. This will provide it with a management board with the authority to guide CONICYT in the execution of its mandate as a principal source of funding of research and innovation in the country. We also believe that there should be a transparent process put in place to streamline and simplify many of the administrative processes used by FONDECYT and FONDEF in their activities. All of this should be undertaken with a view to improving the effectiveness of the Chilean research and innovation system.

Issues: Will the Minister of Education reform the governance structures of CONICYT?
Will CONICYT, FONDECYT and FONDEF make adjustments in their policies and streamline and simplify the administrative procedures which they use in discharging their mandates?

The participation of the private sector

Despite the many good examples of innovative activities by individual Chilean companies, the available data still show that by global standards, investments by private enterprises in technological development are low. Against this background, many informed Chileans accept that past economic success based on exploitation of Chile's natural-resource endowment is unlikely to be sustainable, and that greater contributions are needed from the knowledge base of Chilean society. What is needed is an acceptance by private-sector management that investment in technical change is the surest route to competitiveness in the global economy. As well, recognition is required that even in enterprises that import technology from abroad, a local activity of continuous incremental upgrading is essential.

If the private sector is to engage systematic activities of technological innovation, the next question which arises in all countries, concerns the willingness of government to share in some of the risks.

Issue: How can government engage the private sector in some joint commitments with respect to long-term investments in Chilean science, technology, and innovation?

Policy for support of SMEs

We believe that there is a need for greater attention to be paid in Chile to the problem of improving the management of technological change by SMEs. Also, a clear definition is needed of the role that the state plays in providing assistance. There are now signs that CORFO, assisted by INTEC, is ready to explore options for the creation of some form of technology extension system for Chile. Such an interest should be encouraged, and the inputs of SMEs sought through their organizations.

Issue: Is the Government of Chile prepared to design and implement a technology extension system suited to the needs of Chile's SMEs?

New company start-ups

It would be exceedingly limiting to base development of an innovation system on the presumption that all new, innovative business development will happen in and by existing enterprises. Certainly Chile's present enterprises need to embrace innovation. But it must be realized that current businesses have to be almost entirely focused on succeeding in their current field of endeavour. Therefore, they should rapidly discard ideas that divert them. Thus, an exceedingly important dimension is the successful start of new businesses, often built on new knowledge. We repeatedly heard that there is simply no risk-funding available, let alone the very high risk-funding required for start-up of new knowledge-based business. In addition, some countries have realized that it is not valid to assume that entrepreneurs — the people who see and pursue new opportunities — "just happen." There are educational and training approaches that increase understanding of what an entrepreneur is — and how to be one. New start-ups have been notorious for their rate of failure, but it is evident in successful start-up incubators, that provision of business-mentoring greatly improves the success rate.

We believe these are topics that need to be dealt with in Chile. It is possible that greater linkage with high-risk funding in the USA, which is very sophisticated, could be cultivated. However, this would undoubtedly require greatly enhanced attention to intellectual property protection. Chile might also adapt training and incubator approaches from elsewhere to its advantage.

Issue: Will the Government of Chile take the initiative to foster both the opening up of a market for venture capital and sources of training for entrepreneurs in the business skills which they need?

Policy for the future evolution of technology centres

The Government of Chile, through CORFO, has embarked on a process of policy reformulation to change the mode of financing and functioning of public technological institutes. This work has been accompanied by a parallel evolution in the terms-of-reference of some of the CORFO funds, and in particular of FDI.

We have earlier identified one missing element of this program of reform — the necessary reform of the membership of the governing boards of the institutes. There should be a significant representation of the private sector on the bodies which should have primary responsibility for agreeing with management on the corporate strategies and objectives of the institutes.

An element needing further public discussion relates to the public purposes that government wishes each of these institutes to fulfill. Where government has identified a public purpose — such as providing the research underpinning for managing a natural resource — it should be prepared to negotiate with the institute for the service that is required. For instance, a multi-year performance contract should be priced at market rates and include full overheads.

Issues: Is government prepared to reform the governance structures of technology institutes, and competitive funds, to provide for adequate representation of the private sector on the respective boards?

Will government negotiate performance contracts for those activities which it will expect the institutes to perform in support of public purposes and will it pay fair market prices and full overheads for services rendered?

Linking science, technology and innovation activities to regional development

We have seen that the commitment of the Government of Chile to the decentralization of spending power to regional governments is creating possibilities for regional spending on science, technology and innovation. In some cases, monies will come from the budgets of regional authorities; in others, as with INIA, it will come via introducing a regional voice into the spending decisions of a national program. These signs should provide particular encouragement to the universities and research centres outside of Santiago that should enjoy a natural advantage in competing for regional support.

Issue: How can regional authorities be convinced to allocate some of their spending to the promotion of innovative solutions to regional problems?

Human resource and institutional development issues

We sense that Chile has placed insufficient priority on HRD and on institutional development in resource allocation decisions affecting science, technology and innovation. The new MECESUP project is a good step in the direction of correcting this imbalance. But we see a clear need for more attention to be paid to training new people and to finding employment for them within the NSI. Without such attention, the research community will continue to age.

At the institutional level, we see a need to go beyond traditional investments in training people in the sciences and engineering, to introduce a needed emphasis on research management and on the commercial skills needed to successfully introduce an innovation into a marketplace.

Issues: Will Chile, and in particular its financing bodies, allocate increased resources to HRD to counteract the visible aging trend in many of its science, engineering and technology institutions?

Will more attention, in institutional capacity building, be paid to the need to strengthen the technology management and commercial skills of key staff?

A first discussion of the findings

Introduction

On 11 January 1998, CONICYT organized a meeting at which approximately 90 invited participants were offered the opportunity to comment on and to discuss the findings of the report with the four members of the review team, all of whom were present. The participants were primarily drawn from universities, government ministries and agencies, and from public technological institutes. The meeting was chaired by Dr. Mauricio Sarrazin A., the President of CONICYT.

These notes provide an account of the proceedings — but not in the chronological order of the day's debate. The order was rearranged so that all questions and comments related to a given topic appear under the appropriate session, even though during the meeting the issue might have been raised during others. In the reports of individual sessions, texts labelled as "Questions" or "Comments" were presented by the audience, either orally or in writing, while the "Replies" were from the members of the review panel.

Prior to the first formal session, the leader of the review team provided a summary of the 29 written comments on the report, which had been submitted prior to the opening of the meeting.[15]

Of the comments received in advance of the meeting:

- sixteen were from eight different universities (7 of these institutions were members of the Consejo de Rectores whereas one was private): six were signed by senior officials of the university involved (rectors or vice-rectors), three formally by Deans on behalf of their faculties, and seven by individual professors (one of this last group was signed by fourteen holders of Cátedras Presidenciales);
- four came from scientific societies;
- one was submitted jointly by the Consejos Superiores de Ciencia y Desarrollo Tecnológico de FONDECYT;
- two were from government ministries;
- two were from public technology centres;
- one was from a chamber of industry; and
- three were from officials within CONICYT.

[15] We received two additional comments on the day of our meeting with public technological institutes. In general, their comments were similar to those we have included in this report.

The report has generated significant and thoughtful comment on important issues, and we were impressed with the reflective and generally constructive responses submitted in what was a brief time period of time during a holiday season.

The review process

Two of the written comments questioned the process by which the review was carried out. They objected to the extensive use of quotations from those interviewed, arguing that many of the comments were erroneous, ill informed or out-of-date. Our reply was in two parts.

1. The report announced its intention to act as a "mirror," to reflect back the current state of debate on the support of science, technology and innovation in the country. It did so, while always seeking to clearly distinguish between those comments which were from Chileans who had been interviewed, and others which represented the opinions of the review team itself.
2. In current thinking on management, it is argued that when the clients of an organization of any kind believe that the organization has problems, then that organization does have problems — perhaps not those identified by the clients but, at the very least, there is evidence of failures of communication.

Two different perspectives

The written responses to the report could be divided by the perspectives which the writers believed were appropriate for analyzing and financing science, technology and innovation activities within Chile.

The first was held by a minority of those responding and represented an internal scientific perspective. These commentators argued that the report either ignored or undervalued basic research as an important cultural activity. They saw it as important for Chile to support the search for knowledge in its own right. The majority view agreed with the report's use of a wider societal framework both for the analysis of activities and for the justification of public and private support for science, technology and innovation.

Points of substantial agreement

- The need for a high-level mechanism in government to be responsible for national policies in science, technology and innovation. (Only one set of comments was opposed, on the grounds that the writer feared negative consequences for "free basic research" if either the private sector or the social sciences had a voice in policy-making.)
- The need for reform of the management system at high level in CONICYT and the need to introduce improvements in some of its funding mechanisms.

- The need for significantly increased emphasis on HRD for science, technology and innovation.
- The need, in Chile, to develop increased research activity and national policies for support of health research.

Points of disagreement with the report and our rebuttal

- A substantial minority of respondents to the report felt that it had paid inadequate attention to the important cultural justification for the support of free, basic research. We argue that support of free, basic research that is at the frontiers of knowledge is a necessary, but not a sufficient, basis for a national science agenda.
- A number of commentaries on the report were disappointed by the lack of specific proposals within it. Our point of view was that it was the responsibility of Chileans to develop solutions that would be both practicable and acceptable within the Chilean context.

Points missing from the responses

We expressed disappointment on three aspects of the responses to the report.

1. The lack of any widespread commentary from the private sector — only one chamber of industry had accepted the invitation to provide written comment.
2. The absence of discussion on the "purposes of research in the universities" which were described in Chapter V of the document, arguing that those purposes were discovery — discovery in the context of application, research as a vehicle for the development of high-level human resources, and research as a source of enrichment of undergraduate education.
3. The lack of discussion (except in one submission) of the Innovation Policy Agenda for Chile, set out in Chapter XI, and the lack of suggestions on how a national debate on innovation might be stimulated.

The sessions

Session 1: National policy, resource allocation and regulatory policy

Question: Could the review team provide more detail on the composition of a high-level council for S&T for Chile?

Reply: The report talks of a "high-level mechanism" that should have four elements:

1. a process through which ministers can discuss and decide on matters of science, technology and innovation policy and on the interaction of those with other national policies;
2. a small secretariat to support ministers in these discussions;

3. an analytical capacity to conduct studies to underpin important decisions by government on issues of science, technology or innovation policy; and
4. a source of external advice on these issues.

In most countries, this source of external advice is a high-level council of representatives from the private sector, from the academic sector, and, in some countries, from government. Depending on the choice of the government involved, such a council can provide its advice either in a confidential or in a public manner. We believe that the provision of public advice to government is a healthy practice and stimulates useful discussion — and better public understanding — of often complex issues.

We also pointed out one important, related issue which had not been touched on in our report and which relates to the input of science into high-level decision-making. While our report could be characterized as dealing with "policies for science," there is growing recognition that countries must make adequate provision for inputs of "science for policy." As examples, the team cited two significant controversies now current in Canada. The first deals with the adequacy and use of scientific advice in the management of Canada's Atlantic Fisheries, which have suffered catastrophic collapse. The second deals with the contamination of human blood destined for use in transfusions, by the vectors of AIDS and of Hepatitis-C during years when early diagnostic tests were already available. Policy mechanisms need to understand how to provide and use scientific advice on major issues of public policy of the day.

Question: Should the social sciences have a voice in policies for the natural sciences given the history of ideological differences and of failed social experiments in Chile?

Reply: Setting policies for S&T in a country requires consideration of the social and economic context within it. Social and human sciences can make contributions to such discussions. Each person participating in formal advisory mechanisms has a responsibility to provide advice based on their professional knowledge and judgment. Appointments of people with open minds and with sound and rational judgment are necessary. We would be opposed to blanket exclusion from advisory mechanisms of any group solely based on their disciplinary affiliation.

Comment: The report appears to convey that basic research is significant **only** if it makes a direct contribution to economic development. There is a need to extend the discussion if such a view is to be justified.

Reply: The report does not, in fact, advance that opinion, even though some readers of the report argue that it does. We argue that basic research is important as a source of new knowledge in general, and that it has an increasingly important role to generate new knowledge in the context of the eventual application of that knowledge. It is also an important component of the environment for research training. A society that wishes to make use of knowledge coming from basic research needs to provide for many other functions within its NSI, and to foster and facilitate interactions between basic research and these other activities, including applied research.

The report then looks at how these constructive interactions might be fostered. Additionally, our report recognizes that in addition to providing knowledge for its own sake and contributing knowledge related to economic development, basic research also contributes to teaching and to social development. Hence, for example, our proposal that more attention be paid to health research. We have probably not adequately conveyed that we mean research in the broadest sense, particularly including research in the context of application — not just applied research. In many respects, what needs to be sought out is a convergence of free research with opportunities to do research that will be related to matters of direct interest to Chile.

What the report does not support is the simplistic argument that simply providing funding to "free, basic research" — by implication on subjects decided by trends in the international scientific literature — will automatically lead to optimized national economic development.

Comment: One of the major gaps is an adequate database to inform decision-making. Knowledge of what is actually happening is the heart of coordination. There is a real need for a management tool.

Reply: We have commented on various aspects of this important issue. We support both the idea of providing a "science budget" within government to assist ministers in decision-making, and the idea of improving the availability of statistical information, particularly on industrial R&D expenditures.[16]

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[16] Outside the formal meeting, we were informed that the present system of corporate taxation acts as a disincentive to revealing R&D expenditures, since they are not accepted as legitimate business expenditures which should be paid from pre-tax income. Instead, they are viewed as investments that should be financed from after-tax profits. If this description is accurate, steps should be taken to remove this disincentive to innovative activity.

Session 2: Financing instruments, especially those managed by CONICYT

Comment: The research system in Chile, particularly as it deals with research in the universities, suffers from many problems, some of them identified in the report. These include:

- inadequacy of the salaries of researchers (and the distortions introduced in the system when salary supplements are elements of programs of research support);
- the lack of a formal "budget for Science" in the Government of Chile;
- the small size of the research community;
- the low rate of publication by Chilean scientists (the national average is one publication every five years);
- the lack of adequate support for postgraduate (and undergraduate) students;
- the bias toward part-time appointments in the universities which makes participation in research much more difficult; and
- the lack of a culture of innovation, even among scientists.

This situation calls for a follow-up, in-depth study of the universities and of other (public) research institutions and the examination of better schemes for salary support such as the Mexican Sistema de Investigadores Nacionales (System of National Researchers).

Reply: We believe that there is a need in Chile to have available a complex array of funding modalities for the support of the research activities of individuals, groups, networks, and institutions. However, government should not, in the long term, be seen as the sole source of such support. Experience in many countries, both developed and developing, suggests that when government financing is complemented by increasing support from private-sector sources, all types of research — from the freest of basic research to the most applied activities of technological development — all enjoy expanded opportunities.

Comment: FONDECYT is a mainstay for the support of Chilean researchers and is of enormous importance. But there has recently emerged a serious problem in ranking of researchers. As of 1998, each is allocated an alphabetic "quality classification" based on past productivity and designed to affect future funding. Those classified as level "D" are automatically excluded from funding. The consequences are potentially disastrous for young persons, and for those who do not have graduate degrees. The problem is seen to relate to a rigid categorization of researchers, without sensitivity to differences among disciplines or to lack of experience.

Reply: As one example, in South Africa, the nearest equivalent body to FONDECYT — the Foundation for Research Development (FRD) — has operated a ranking system for years, beginning long before that country's 1994 constitutional change. One positive element of that system was its use of a separate stream for researchers younger than 35. In that category, the very best are rated in category "P" (Presidential Awardees). They can acquire funding levels equivalent to experienced researchers of category "B." Researchers in a second category, "Y," are also deemed eligible for support at a more modest level, but adequate to permit them to make a start as independent investigators. In each of the "P" and "Y" categories, the actual amount of the award is related to a number of additional factors including the number of graduate students involved, and the relative financial requirements of different disciplines.

Amendments were introduced to allow for the fairer treatment of researchers from among the previously disadvantaged and marginalized sectors of South African society, including provision of mentorships for researchers from those communities.

The review panel believes that any ranking system needs to be introduced with care and not be simply a conservative device to reduce new entries into the field.

Around the world there are diverse modes of approach for new researchers, in which there is treatment tailored to their stage of development. The Canadian model for young researchers uses the same review committee for young researchers, but in a context of proactive support to give them a chance to demonstrate their intellectual potential for 3–6 years before being subject to the regular competition criteria. It is not a separate stream, but a developmental one. Experience suggests that review panels (study groups) are positively influenced by having to review young people and that "segregation" in a different funding modality is not an absolute necessity.

In funding competitions for the allocation of support for research infrastructure, some countries, again including Canada, have set up separate allocations for researchers who are under 35.

Chile needs to improve its system for training young researchers and for introducing them into the ranks of active research. Careful consideration should be given to designing an effective system for their support, possibly drawing on some foreign examples.

Comment: Some aspects of FONDECYT operations are opaque and non-transparent. In particular there is concern about the conflicts-of-interest involved in the recurring cases of researchers who serve as peers or panel members for competitions in which they themselves are seeking funding.

Reply: This problem occurs in all national financing systems that employ peer review and do not leave decision-making in the hands of government officials. The option of excluding experienced and active researchers from the review process is not a good one. It is necessary to recognize this and to provide written policy that describes how problems will be avoided. Such a statement could include elements such as:

- reviewers with an application for funding must be absent for any discussion touching on their proposal;
- foreign peers must be employed in the review of proposals from nationals who are engaged in the review process; and
- in countries offering multi-year grants, annual attempts should be made to minimize the number of people in the evaluation system who are also presenting funding proposals.

On a more general level, we propose that there is a need to develop a system in which there is more confidence in both the decision-makers and in the processes whereby their decisions are made. One element of a process of confidence building in the case of FONDECYT might be an improvement in the extent of public consultations prior to the appointment of new members of its Consejos Superiores. However, much needs to be done to create interactions and relationships among researchers to overcome the negative behavioural stereotypes, the lack of communities, and the excessive fragmentation into small, isolated groups.

Comment: Concern was expressed concerning resource allocations within FONDECYT, for the social sciences and humanities. The distribution seen as very unfair, despite their enormous importance. There was a call for "a more ethical and rational distribution of funds."

Reply: The report data (see Table 10), which deal only with numbers of FONDECYT's projects and not actual funding levels, show a heavy preponderance of support to fields other than the social sciences and humanities (73 percent versus 27 percent in the period 1996–1998). On the positive side, the share allocated to the social sciences and humanities in those years (27 percent) is an improvement over the 22.5 percent share over the period 1982–1995.

That said, and noting the review panel's acknowledgement of the importance of support to the social sciences and humanities, we do not know of any means of constructing a distribution of funds that would be universally accepted as being intrinsically "more ethical and rational."

The allocation of resources is one of the most important and difficult of all public policy processes. In the case of allocations to research, factors to be considered include the number of active and proficient researchers seeking funds in each area; the nature of their needs (not all areas of research have the same needs for advanced and expensive equipment); and perceptions of the importance of supporting research in the context of national economic, social, environmental, or cultural requirements. In the long term, it is more likely that a review of trends and changes in the overall pattern of financing will provide more meaningful indicators of policy than any absolute comparison of amounts of money allocated to one area or another. Hence, this allows judgment of whether or not the policy is rational and defensible, against which the interpretation of national needs can be measured.

Comment: Contradictory regulations abound within CONICYT and many are not designed with a view to improving the performance of science. For example, FONDEF regulations allow the purchase of large equipment, but not the provision of operating funds. On the other hand, the regulations allow only the purchase of relatively small pieces of equipment, but do allow funds for operating that equipment. However, FONDEF and FONDECYT grants cannot be held simultaneously by the same individual.

Reply: In many countries, including Chile, regulations are frequently introduced to cope with individual difficult cases. But rarely is there an examination of the overall pattern of regulations in effect. It would be an interesting exercise within CONICYT (and within PIT as well) to consider a systematic challenge to every currently-used restrictive regulation against the criterion of its contribution to the development of research.

Comment: FONDECYT is one of the key tools for the development of science in Chile. However, it is seriously under-funded, being kept at a relatively constant level for several years

Reply: We acknowledge that the overall level of funding from both the public and private sectors in Chile is low. As a result, all funding modalities need increased allocations, including FONDECYT. Increases are needed not only for performing research, but also for important matters such as training of new generations of young people, for the acquisition of new and expensive

equipment, and for the diffusion of new knowledge and technologies to users in the country, to name but a few.

Question: How should Chile enhance the regional element of this debate?

Reply: The report recognizes that, in the eyes of many, the current distribution of research funding in the country is disproportionately concentrated in institutions in metropolitan Santiago. We have visited institutions in the regions that were making real efforts to increase their research capacities, and to relate to regional issues and problems.

A first start to ensuring an appropriate regional distribution of funding may be possible via the activities of the Ministry of Education's MECESUP project and its introduction of an accreditation scheme for graduate studies. Such a scheme will require the public introduction of performance benchmarks against which candidates for accreditation will be judged. Adequate progress toward accreditation by an institution will be one indicator of the quality of commitment to research exhibited within each institution.

The new accreditation system being introduced through MECESUP offers the opportunity to establish baseline measures of institutional commitment to research and of the on-going quality of that research. To assist institutions to upgrade their performance, CONICYT should consider introducing some special, time-limited initiatives to allow institutions an opportunity to demonstrate their potential. This could be a process similar to the one we favour for the treatment of new young researchers when they enter research.

Comment: The report supports the original concept of FONDAP projects as permitting a move toward newer, multidisciplinary and inter-institutional types of research projects and networks. However, the FONDECYT councils have now changed the rules, to focus support on "Centres" within single institutions — a step backwards.

Reply: At the time of the meeting, we had not heard of this change but indicated that it favoured experimentation with a range of modalities for the support of research that goes beyond the financing of traditional "Centres" within a given university, even if external researchers were to become "associated" with the Centre.

[Note: Later on, CONICYT provided a copy of the new rules, saying that the changes had been introduced to assure adequate administrative support and management of the FONDAP grant. We looked at the revised documentation and concluded that the changes had gone far beyond simply

assuring the designation of one group to be responsible for the administration of projects. These new regulations effectively prevent the allocation of FONDAP Funds to consortia of universities of the types that are emerging, successfully, elsewhere in the world. We believe that the councils of FONDECYT should reconsider these regulations in the interests of the healthy development of research activities in the country.]

Session 3: Performance functions in the universities, technology institutes and enterprises

Comment: Concern was expressed with respect to government funding policies in regard to universities. Specifically, these points were made:

- There is no support for the research function of universities leading to problems of the maintenance and operation of research infrastructure.
- There are concerns over the adequacy of the pipeline of new people and for the initiation of new areas of investigation.
- FONDECYT is seen as an adequate mechanism for maintenance of what is now in place, but not for the establishment of new groups or lines of investigation. Consider, for example, the difficulties of initiating programs in such areas as genomics, or bioinformatics.

Reply: Chile needs to develop a multi-faceted strategy for support of the institutions in which it expects research to take place. Such a strategy would need to include specific including institutional initiatives, MECESUP, a change in the university financing system, the provision of overheads on grants or contracts for research, special support for infrastructure (including a fund for major equipment) and diversification of sources of support for research, including a significantly expanded role for the private sector.

It is essential to be certain that the universities can mount and sustain the research infrastructure and support systems that are necessary for first-rate research actually to be done.

One positive practice in Chile noted by the review team was that of changing all of the higher officials in a university when a new rector is appointed. This affords a periodic opportunity for the introduction of new perspectives and interests into significant institutions.

[Note: During this session, no comment was offered by members of the audience with respect to the current financing problems being faced by Chile's public technological institutions. In introducing the session, we underlined our concern that the current funding system being implemented by CORFO for the five institutes under its jurisdiction, runs the risk of

preventing necessary investment in the long-term development of technological capacities needed in Chile's NSI.]

Session 4: Human resource development and infrastructure

Comment: The review team is unenthusiastic about the role played by the Cátedras Presidenciales within the Chilean S&T system. In particular, it ignores the contribution they are making to the training of young researchers. With 40 Cátedras currently active, there are between 40 and 80 young researchers working closely with senior, and respected investigators.

Reply: The report actually stated that "the inclusion of a need to support one younger researcher, while welcome, is not adequate in view of the magnitude of the problem being faced by Chile with respect to the aging of its scientific community." We think that there is the need for other, additional schemes to increase the number of young Chileans in research and that some of the schemes need to be designed to give the younger people a chance to work independently, on their own ideas.

Comment: There is significant, unused capacity to train graduate students in Chile today, and this despite the widely acknowledged need to inject increasing numbers of young people into the research system. There is an urgent need for Chile to take steps to address this matter by increasing the number of fellowships and changing the support policies. In the early proposals for the CONICYT Budget of 1999, the scientific community mounted a campaign to reverse a proposed cut from 75 to 54 in the planned number of fellowships. The campaign was successful and the number is now set at 95 (including those who will be supported under MECESUP). But there are anomalies in the system — FONDAP rules preclude post-graduate students from being supported on FONDAP funds.

Suggestions by CONICYT that there was not a sufficient, qualified demand for higher numbers of scholarships were vigorously contested. Senior university officials argued that there were probably 200–300 candidates available.

Reply: We believe that Chile must provide a substantial increase in the number of young people receiving research training, not only to open possibilities of academic careers, but to provide rigorous training in the solving of complex problems to people who will later pursue careers in many different areas of Chilean life.

Thus, it appears that there is unfilled capacity for graduate students, although there are highly qualified students seeking training. However, the

level of funding support is too low to increase numbers in the short term. Thus in this situation, the likely result is that Chile cannot move ahead in research or innovation at the rate that it might.

Question: Will all of the proposed attention to increasing the numbers of young people entering research have the final result of diluting the support of existing qualified researchers who are already inadequately funded?

Reply: First, not all young people receiving graduate training in research will, or should, seek academic careers. Second, there is a need to expand Chilean investments in research and training from all sources, both public and private. The more open the research community is to situating its activities "in the context of national needs and interests," the more likely is the possibility of obtaining improved support.

Question: Within the current financial situation, will astronomy be able to attract increased investment in research and research training? Should there be a special policy to exploit the special opportunities afforded by excess observing time?

Reply: Chile is in a unique position, given that its opportunity to utilize the superb viewing conditions provided by its geography has been dramatically expanded by a series of major foreign investments in astronomical observatories. As indicated in the question and in the report, Chile has negotiated the use of amounts of observatory viewing time, which is several times larger than its current small group of astronomers can use.

We think that Chile needs to consider a multi-pronged approach to expansion of its astronomical activity. This needs to include:

- exploration by the present group of astronomers of the current apparent low-interest among young Chileans in careers in the field, which could be linked to perceptions of low employment opportunities at the end of graduate studies;
- consideration by the universities of their level of interest in promoting strong astronomy groups within their institution;
- exploration of the feasibility of using the unused hours of viewing time as a lever to obtain funding for necessary ancillary equipment and graduate scholarships for young people;
- aggressive use by astronomy of existing funding modalities; and
- consideration by CONICYT and government as to whether their would be a justification for a FONDAP award to a suitably constituted consortium in Astronomy.

Comment: With its limited resources, Chile has been able to attract back to the country an important number of internationally known scientists. This is a credit to Chile. They can make significant contributions internationally to science while working from bases in Chile, thanks to the availability of electronic networking that provides easy contact with colleagues in any part of the world.

Reply: In addition to attracting scientists back, which is a significant activity, Chile might also explore temporary linkage programs in which expatriate scientists would spend part of their working year in the country.

We also noted that in other countries, electronic networking, coupled with national networks of researchers, has made it possible for good researchers to remain in regional universities while being active participants in national research activities at the forefront of scientific research and technology development.

Concluding remarks

Comment: Many of the ideas in the report of the review team are not new in Chile. Most are to be found in the report of the Consejo Asesor de CONICYT published in 1995 (Consejo Asesor de CONICYT 1995).

Reply: More than needing a better institutional memory, Chile needs to pay more attention to those steps which will incorporate implementation of those measures that enjoy wide support. There is a need for people to champion such actions that are widely perceived as being necessary.

The leader of the review team thanked the participants for the open spirit which they brought to the debate and thanked all of those responsible for the warm welcomes which had been received throughout the process of preparing the report.

In closing the meeting, the President of CONICYT expressed the hope that, on this occasion, a way would be found for Chile to move forward in its activities in science, in technology, and in innovation.

Appendices

Appendix 1: Members of the study team

The authors

Team leader:

Mr. James Mullin President, Mullin Consulting Ltd. Canada	Former Vice President Program, the International Development Research Centre, Canada; former Chair, the Committee on Science and Technology Policy, The Organization For Economic Cooperation and Development

Team members:

Dr. Robert M. Adam Deputy Director General Department of Arts, Culture, Science and Technology Government of South Africa	Responsible for the articulation of the Science, Technology and Innovation Policy of the Government of South Africa; and for implementation of the reform of the governmental system of science, engineering and technology institutions
Dr. Janet E. Halliwell President, JEH Associates Ltd. Canada	Former Chair, Science Council of Canada; former Chair, Nova Scotia Council on Higher Education; former Director General, Research Grants, The Natural Sciences and Engineering Research Council of Canada
Dr. Larry P. Milligan Vice President, Research University of Guelph Canada	Fellow of the Royal Society of Canada; former member of the Prime Minister of Canada's National Advisory Board on Science and Technology

Appendix 2: Schedule of interviews

Monday, 3 August 1998

Morning	1. CONICYT — meeting to confirm schedule and to obtain documentation
	2. Meeting with the Council of FONDEF
Afternoon	Group meeting with representatives of INIA, CIMM, IFOP, Fundación Chile and FIA to discuss common issues

Tuesday, 4 August 1998

Morning	Ministerio de Economía, Dirección de la Programa Innovación Tecnológica
Afternoon	1. Meeting with the Consejo Superior de FONDECYT
	2. Meeting with Director of FONDAP — "Oceanografía y Biología Marina"

Wednesday, 5 August 1998

Morning	1. Meeting with the Management of FONTEC
	2. Meeting with the Management of FDI
	3. Meeting with the Management of INFOR
Afternoon	1. Meeting with the Vice President and some members of the Comité Asesor de la Presidencia
	2. Meeting with the Ministro de Educación

Thursday, 6 August 1998

Morning	Group 1: Universidad de Chile — meeting Rector and with leaders of groups supported by FONDECYT and FONDEF
	Group 2: 1. Meeting with CORFO
	2. Pontificia Universidad Católica de Chile — meeting with leaders of groups supported by FONDECYT and FONDEF
Afternoon	Group 1: Universidad de Santiago — meeting Rector with leaders of groups supported by FONDEF and FONDECYT
	Group 2: Universidad Metropolitana de Ciencias de Educación — meeting with Rector, senior officials and participants in groups supported by FONDECYT and FONDEF

Friday, 7 August 1998

Morning	1. Meeting with representatives of companies supported by FONDEF
	2. Meeting with the Minister of Foreign Affairs
Afternoon	Meeting with representatives of firms supported by FONTEC, FIA and FDI

Saturday, 8 August 1998

All day	Internal meeting of review team

Sunday, 9 August 1998

Afternoon	Travel by review team members to regions

Monday, 10 August 1998

Antofagasta	Morning:	Universidad Católica del Norte — meeting Rector and with leaders of groups supported by FONDECYT and FONDEF
	Afternoon:	Universidad de Antofagasta — meeting with leaders of groups supported by FONDECYT and FONDEF
Concepción	Morning:	Universidad de Concepción — meeting with Rector and senior officers and with leaders of groups supported by FONDECYT and FONDEF
	Afternoon:	Universidad del Bio-Bio — meeting with Rector elect and then with leaders of groups supported by FONDECYT and FONDEF
Valdivia	All day:	Universidad Austral de Chile — meeting with leaders of groups supported by FONDECYT and FONDEF
Valparaíso	Morning:	Universidad Católica de Valparaíso —meeting with senior officials and leaders of groups supported by FONDECYT and FONDEF
	Afternoon:	Universidad de Valparaíso — meeting with senior officials and leaders of groups supported by FONDECYT and FONDEF

Tuesday, 11 August 1998

Morning	Group 1:	Meeting with the management of INIA
	Group 2:	Meeting with the management of CIMM
Afternoon	Group 1:	Meeting with the management of IFOP (in Valparaíso)
	Group 2:	Meeting with the management of INTEC

Wednesday, 12 August 1998

Morning	Group 1:	Management of INFOR
	Group 2:	Management of Fundación Chile
Afternoon	All members: Meeting with official responsible for MECESUP	
	Group 1:	Meeting with the Vice-Rector, Universidad Nacional Andrés Bello
	Group 2:	Meeting with the directors of services within CONICYT

Thursday, 13 August 1998

Morning	Group 1:	Meetings with CONICYT staff re functioning of FONDECYT and FONDEF
	Group 2:	Meeting with senior industrialists
Afternoon	1. Ministerio de Hacienda, Oficina del Presupuesto Nacional	
	2. MINEPLAN	

Friday, 14 August 1998

Morning	Internal meeting of review team to prepare preliminary conclusions
Afternoon	1. Meeting with CONICYT and guests to present preliminary conclusions of the review
	2. Meeting with the Ministro de Educación

Appendix 3: The functions of a national system of innovation

Exclusive functions of government

Policy and resource allocation functions

- Formulation, implementation monitoring, plus review of policies and, in some countries, plans concerning national S&T activities
- Linkage to other policy domains (such as dealing with the economy, trade, education, health, environment, defence)
- Allocation of resources to S&T from overall budgets and first-order allocation among activities
- Creation of incentive schemes to stimulate innovation and other technical activities
- Provision of a capacity to implement policies and to coordinate appropriate activities
- Provision of a capacity for forecasting and assessing the likely directions of technical change

Regulatory functions

- Creation of a national system for metrology, standardization, calibration
- Creation of a national system for the identification and protection of intellectual property
- Creation of national systems for the protection of safety, health and the environment

Shared implementation functions

Financing of innovation-related activities

- Management of financing systems appropriate to the implementation of the other functions of the system
- Use of government purchasing-power as a stimulus to innovation in the production of the goods and services which it requires

Performance functions

- Performance of R&D
- Creation of joint ventures, networks or consortia for R&D
- Provision of technical services including product testing, trouble shooting, calibration, resource surveys

- Provision of mechanisms to link R&D outputs to practical use, including brokerage services
- Provision of mechanisms to improve access by SMEs to needed technology
- Provision of linkages to regional interests, programs and activities within the country
- Provision of linkages to international S&T activities
- Provision of mechanisms for evaluating, acquiring and diffusing best-practice technologies
- Creation of innovative goods, processes and services embodying the results of S&T activities and their introduction into appropriate markets
- Creation of joint ventures, networks or consortia for the exploitation of intellectual property

Human resource development and capacity-building functions

- Provision of programs and facilities for the education and training of S&T personnel
- Provision of programs to promote international training of S&T personnel
- Provision of programs to promote improved management of technology
- Creation of institutional capacity in S&T
- Provision of mechanisms to maintain the vitality of the national S&T community
- Stimulation of public interest in and support of national initiatives in S&T

Infrastructure functions

- Establishment, operation and maintenance of information services (including libraries, databases, statistical services, a system of indicators, communications systems)
- Establishment, operation and maintenance of technical services (such as metrology, standardization, or calibration) and services to promote improved industrial design
- Establishment, operation and maintenance of mechanisms to promote productivity and/or competitiveness
- Establishment, operation and maintenance of a system of awarding, recording and protecting intellectual property
- Establishment, operation and maintenance of mechanisms to ensure the protection of safety, health, and the environment
- Establishment, operation, and maintenance of major national facilities for research

Appendix 4: Groupings of stakeholders in Chile's national system of innovation

Stakeholder Group	Subgroup
Government	• Central policy and financing agencies, where they exist • Relevant congressional committees • Departments of government and their programs • Financing institutions and programs including CONICYT and PIT • State technological institutes and laboratories attached to ministries • The armed forces • La Comisión Asesora Presidencial en Ciencia, la Comisión Nacional de Nuevas Tecnologías de Información y Comunicación and other Advisory Bodies
Business	• Large Chilean corporations • State corporations, such as CODELCO • Subsidiaries of multinational corporations operating in Chile • Small- and medium-scale enterprises • Business associations and Chambers of Commerce • Banks, sources of venture capital and other financial institutions • Farmers • Farmers' cooperatives and associations
Education and training	• Universities of all kinds • El Consejo de Rectores de las Universidades Chilenas • Technical colleges • Private training institutions • Primary and secondary schools
Organized civil society	• Labour unions, especially those in sectors facing rapid technical change • Professional and academic societies • NGOs interested in or performing research • NGOs interested in technical change
Interested outsiders	• Latin American governments and the participants in their national systems of innovation • Industrialized countries, including both official development-assistance agencies and participants in their NSIs • Multilateral agencies active in Chile (World Bank, IDB)

Appendix 5: Some examples of human resource development programs from outside Chile

Example #1: Technology and Human Resources for Industry Programme (THRIP) — South Africa

Program objectives

- To contribute toward increasing the number and quality of human resources with appropriate technological and managerial skills for industry.
- To promote research support to researchers in higher education and research institutes with the aim of developing skills for the value-added exploitation of S&T.
- To stimulate industry and the public sector to increase its investment in research, technology development, and innovation promotion.

Special features

- Provides a new and enhanced educational experience within the context of technology development.
- Participation by students in cross-sectoral projects of technology development.
- Collaboration among industry, the tertiary academic sector and government science, engineering, and technology.

Funding characteristics

- Cost-shared

Example #2: Industrial Research Fellowships (IRP) — Canada

Program objectives

- To encourage recent Ph.D. graduates to gain experience and seek careers in industry.
- To promote awareness in industry of the capabilities of universities and university research.
- To facilitate the transfer of expertise and technology.
- To provide an opportunity for Ph.D. graduates to gain experience in industrial R&D.

Special features

- Open to candidates who have completed their doctoral degree in the last five years, though extensions are allowed for maternity leave.

- Promotion of Fellows involvement in research and research management
- Good rate of transfer from Fellowship to permanent positions with same or related firm.

Funding characteristics

- Base salary provided by federal program, with salary supplements and research costs provided by the firm.

Example #3: MettNet — Canada

Rather than a government program, MettNet is a not-for-profit federal corporation that acts as a broker to assist technology-driven SMEs in improving their overall performance through the application of resources found principally in universities, financial institutions, and technical institutes.

Mode of operation

- Maps the technology and technology-management needs of a target population of SMEs through direct interaction with them.
- Analyses and identifies areas where university resources — especially undergraduate or graduate students, student projects, or recent graduates as potential employees — could be brought to bear on industry needs.
- Brokers a relationship with "suppliers," often using the power of undergraduate and graduate student projects.
- Monitors, mentors, and assesses project outcomes.

Special characteristics

- MettNet acts in areas (SMEs) where government programs are often not successful.
- Often creates first linkage between SMEs and universities — a link that can become self-sustaining.
- Promotes solutions that blend technology and technology management.
- Active involvement of SMEs.

Funding characteristics

- A mix of client fee-for-service, and core funding from banks, universities, and government R&D programs.

Example #4: Research chairs, management of technological change — Canada

Program objectives

- To improve the management of technological change and innovation in organizations so as to enhance competitiveness.
- To increase technological entrepreneurship.
- To facilitate the adoption of new technology in the workplace and in society in general.
- To improve the development of public policy and public understanding related to technological change.
- To improve education and training in the management of technological change within and across existing disciplines.

Special features

- Proposals expected to feature partnership with private-sector sponsors.
- Jointly supported by agencies responsible for science and engineering and social sciences and humanities.
- Provides an opportunity for firms to pick-and-choose potential employees.

Funding Characteristics

- Cost sharing — funding agency, private sector, institution.

Appendix 6: Acronyms

Acronym	Definition
APEC	Asia-Pacific Economic Cooperation
CGIAR	Consultative Group on International Agricultural Research
CIMM	Centro de Investigación Minera y Metalúrgica (Research Centre for Mining and Metallurgy)
CIREN	Centro de Información de Recursos Naturales (Natural Resources Information Centre)
COCHEN	Comisión Chilena de Energía Nuclear (Chilean Nuclear Energy Commission)
CODELCO	Chilean National Copper Company
COHRAD	Commission on Health Research and Development
CONAF	Corporación Nacional Forestal (National Forest Corporation)
CONICYT	Comisión Nacional de Investigación Científica y Tecnológica (Chilean National Council for Science and Technology)
COPANT	Comisión Panamericana de Normas Técnicas (Pan-American Standards Commission)
CORFO	Corporación de Fomento de la Producción (Corporation for the Promotion of Production)
CSIR	Council for Scientific and Industrial Research [state-funded institution in South Africa]
CSIRO	Council for Scientific and Industrial Research Organisation [state-funded institution in Australia]
CSTP	Committee on Science and Technology Policy [of the OECD]
CTC	Chilean Telecommunications Company (the telephone company)
ENHR	Essential National Health Research
Entel	the Chilean long-distance carrier
ESO	European Southern Observatory
EXPLORA	program which provides information to schoolchildren on S&T
FDI	Fondo de Desarrollo e Innovación (Fund for Development and Innovation)
FIA	Fundación para la Innovación Agraria (Foundation for Innovation in Agriculture)
FIM	Fondo de Investigaciones Mineras (Fund for Mineral Research)
FIP	Fondo de Investigación Pesquera (Fund for Fisheries Research)
FONDAP	Fondos de Estudios Avanzados en Áreas Prioritarias (Funds for Advanced Studies in Priority Areas)
FONDECYT	Fondo Nacional de Desarrollo Científica y Tecnológica (National Fund for Scientific and Technological Development)
FONDEF	Fondo de Fomento al Desarrollo Científico y Tecnológico (Fund for the Promotion of Scientific and Technological Development)
FONSIP	Fondo para Programas y Proyectos de Investigación de Servicio e Interés Publico

FONTEC	Fondo Nacional de Desarrollo Tecnológico y Productivo (National Fund for Technological and Productive Development)
GDP	gross domestic product
HRD	human resource development
IDB	Inter-American Development Bank
IDRC	International Development Research Centre
IFOP	Instituto de Fomento Pesquero (Institute for the Promotion of Fisheries)
INACH	Instituto Antártico Chileno (Chilean Antarctic Institute)
INDAP	Instituto Desarrollo Agropecuario (Agricultural Development Institute)
INFOR	Instituto Nacional Forestal (National Forest Institute)
INH	Instituto Nacional de Hidráulica (National Institute of Hydraulics)
INIA	Instituto Nacional de Investigación Agropecuaria (National Institute for Agricultural Research)
INN	Instituto de Normas Nacional (National Standards Institute)
INTEC	Corporación de Investigaciones Tecnológicas (Corporation for Technological Research)
IP	intellectual property
IRAP	Industrial Research Assistance Program [NRC, Canada]
IRP	Industrial Research Fellowships [Canada]
ISI	International Standards Institution
IT	information technology
MECESUP	Proyecto de Mejoramiento de la Calidad y Equidad de la Educación Superior (Project for the Improvement of Quality and Equity in Higher Education)
MINEPLAN	Ministerio do Planeación (Ministry of Planning)
MINTEK	state-funded institution in South Africa
MMA	millimetre array
NGOs	non-governmental organizations
NRC	National Research Council [Canada]
NSI	national system of innovation
OECD	Organization for Economic Cooperation and Development
PDF	post-doctoral fellowships
PGS	postgraduate studies
PIT	Programa Innovación Tecnológica (Program for Technological Innovation)
QA	quality assurance
R&D	research and development
REUNA	Red Universitaria Nacional (the Chilean Internet network)
S&T	science and technology
SAG	Servicio Agrícola y Ganadero (Agricultural and Livestock Service)
SERNAGEOMIN	Servicio Nacional de Geología y Minería (National Geology and Mining Service)

SET	Science, Engineering and Technology
SME	small- and medium-sized enterprises
SNA	systems network architecture
THRIP	Technology and Human Resources for Industry Programme [South Africa]
TIs	technology institutions
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
USTR	United States' Trade Representative
UUCP	Unix-to-Unix Copy (a file transfer protocol)
WTO	World Trade Organization

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Science, Technology, and Innovation in Chile

James Mullin, Robert M. Adam, Janet E. Halliwell, and Larry P. Milligan

Chile and Canada are two countries who share the challenge of creating and maintaining a vital "national system of innovation" to serve the needs of their resource-based economies. Chile and Canada also have a rich history of research collaboration, largely fostered by the activities of IDRC. With this in mind, and following a conversation between Canadian Prime Minister Jean Chrétien and Chilean President Eduardo Frei in 1997, IDRC and the Chilean National Council for Science and Technology (CONICYT) agreed to collaborate in a review of Chile's policies and programs in science and technology.

Science, Technology, and Innovation in Chile presents the results of that review. It gives the reader a detailed look into Chilean policies of science and technology, using the "national system of innovation" as its point of departure. The book proposes mechanisms for better public-sector coordination, reforms of public-sector technology institutes, and policies for training scientists and engineers. It will appeal to government officials and policymakers in science and technology; academics, researchers, professors, and university students in development studies, policy studies, and Latin American studies; public and private businesses involved, or interested in becoming involved, in the Chilean economy; and donor organizations and NGOs active in Chile and throughout Latin America.

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